THE STATE OF TEXAS.
LEVEE AND DRAINAGE BOARD.
AUSTIN.

THE FIRST TECHNICAL REPORT

OF THE

STATE LEVEE AND DRAINAGE COMMISSIONER

ON THE

Reclamation of the Overflowed Lands.

1912

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DIAGRAMS ILLUSTRATING TEXT.

Flood in the Trinity River, 1908. (Courtesy of the Dallas News.)

LETTER OF TRANSMITTAL.

To His Excellency, Oscar Branch Colquitt, Governor of Texas.

SIR: I have the honor to transmit herewith my first technical report upon the Reclamation of the Overflowed Lands, together with complete topographic levee maps published separately.

In the preparation of this report, it has been the supplemental endeavor to concentrate such technical data at present available, as may be of immediate value to the several improvement districts throughout the State; and in future publications, to fully discuss the engineering principals herein mentioned briefly.

To the former and present members of the State Levee and Drainage Board, Governor Thomas M. Campbell, Governor O. B. Colquitt, Hon. R. V. Davidson, Hon. J. T. Robison, Hon. Jewel P. Lightfoot, Hon. James D. Walthall. and Hon. B. F. Looney, I desire to express my sincere appreciation of their co-operation and support in the work of the department.

In designing the reclamation plans presented, I have the pleasure to acknowledge the valuable assistance and advice of the following gentlemen: Major F. M. Kerr, Chief Engineer of Louisiana; Mr. H. C. Smith, and Mr. Walter H. Hoffman, Assistant State Engineers of Louisiana: Major T. H. Jackson, Corps of Engineers, U. S. Army; Mr. C. G. Elliott, former Chief of Drainage Investigations, U. S. Department of Agriculture; Mr. M. O. Leighton, Chief Hydrographer, and Messrs. E. M. Douglas and Sledge Tatum, Geographers, U. S. Geological Survey.

Respectfully,

ARTHUR ALVORD STILES,
State Levee and Drainage Commissioner.

Austin, Texas, December, 1912.

INTRODUCTION.

The swamp and overflowed lands of Texas exceed in extent the combined areas of the States of New Jersey and Connecticut.

The swamp lands lie chiefly within the coastal plain, and cover about five million acres. The surplus water of this section accumulates locally during the heavy rains of the winter and spring. The natural drainage, generally adequate under normal circumstances, at this time becomes congested; and the area is temporarily inundated. Later in the spring, when the excessive rain water has made its way to tide level, the plain bears no resemblance to a swamp. This extensive, dormant area may therefore be more specifically designated as the undrained lands.

In general, the difference of elevation between these lands and the sea level is amply sufficient for perfect reclamation by means of drainage, through the simple process of improving and straightening the natural water courses, or by supplementing them with artificial canals and lateral ditches. The most serious difficulty is encountered when, with continued development, these passage-ways become overtaxed, and one section is drained at the expense of another. To guard against this condition, which always grows more and more acute, each district should be designed in the beginning as part of a complete and adequate system, based strictly upon the existing topographic and hydrographic conditions. The perfecting of such a system is impossible in the absence of an accurate and detailed topographic survey and map of the entire local watershed, supported by hydraulic data obtained in the field.

Since the establishment of this department, no actual surveys have been made for drainage purposes in the coastal plain. As hereinafter mentioned, upon the request of the State Levee and Drainage Commissioner, the U. S. Department of Agriculture undertook this branch of the work in Texas, and will soon make a report upon the subject. Being assisted in this manner by the federal bureau, this department has been advantageously enabled to confine its first work to the single subject of reclamation by levees. But with the competent topographic field force now being trained, the operations of the Board can rapidly be continued to the second division of the work authorized; and complete drainage surveys may hereafter be made as required in the various sections of the State.

After being reclaimed the productiveness of the undrained lands has been abundantly demonstrated. In the present unimproved state, they can be bought for $10.00 to $20.00 per acre. They can be effectively drained for about $10.00 to $15.00 per acre in addition to the original cost, and when so drained, they are sold for $50.00 and $60.00 per acre.

The overflowed lands constitute the low valleys or "flood-plains" of the rivers and larger tributary streams that traverse the eastern quarter and southern portion of the State. The total overflowed area is estimated at three million acres.

The river flood-plains are formed by alluvial deposits of great depth,

and are bounded on either side by abrupt foot hills, from which all tributary drainage makes its way to the river. The main channel of the river follows a winding course, or is said to "meander" through its flood-plain. As a result, the channel is located near the foot hills first upon one side of the flood-plain, then near those upon the opposite side, thus dividing the overflowed valley into a series of distinct topographic and hydrographic precincts. Normally, this meandering channel is capable of carrying the waters of the river and all of its tributaries, thereby furnishing complete drainage for the overflowed lands, but when the flood stage is reached the channel becomes overcharged and the surplus water passes out over the channel banks, and gradually covers the entire flood-plain to the base of the hills on either side. This condition usually lasts for about ten to fifteen days, when the flood in the channel runs out, and the lands previously overflowed are again properly drained by the passage of the surplus water back to the channel.

The floods in these rivers are caused by torrential rains, usually in spring and summer, falling upon distant watersheds. The overflows do not occur every year, yet they have sometimes occurred twice in the same year. It is known that the floods are uncertain, nevertheless the fear of their coming is constant and therefore demoralizing.

The reclamation of the overflowed lands is accomplished by levees, built along the banks of the meandering main stream channel. The levees necessarily begin and end at the high ground, and their effect is simply to enlarge the channel by increasing the height of its banks. If sufficiently enlarged by this means, the channel is enabled to convey all of the flood waters, which then do not spread out over the flood-plain.

Reclamation by drainage and reclamation by levees become associated problems where the trans-state or "through" rivers cross the coastal plain. Here the conditions are far different from those that exist in the upper reaches of the river. There are no foot-hills and the flood-plain becomes more or less indeterminate. Instead of necessarily joining the river, the side drainage may go away from the river. This is illustrated on the lower Brazos in the vicinity of the State Farms, where a continuous levee about sixty miles in length, and without sluice-gate openings, beginning at high-ground above Sugarland, and following the river front, would end at tide water near Velasco. It would thus confine to its channel the flood waters of the Brazos, meanwhile permitting the local drainage to be conducted to the Gulf at a different point, by passing out through an ancient channel called Oyster Creek.

The following report deals exclusively with the reclamation of the overflowed lands by means of levees.

Great Flood of 1899.—Brazos River. State Convict Farms at Sartortia. Fields of sugar cane, partially submerged and wholly destroyed, appear to the right and left in the distance. Much of the railroad was swept away, and the inhabitants fled from the valley by means of small boats. (Courtesy of Collier's Weekly.)

Great Flood of 1899.—Brazos River near Chapel Hill. A "laid by" cotton crop estimated at a bale to the acre lies six feet beneath this water. About a million bales of Texas river cotton went to similar destruction during this flood. (Courtesy of Collier's Weekly.)

CHAPTER I.

THE OVERFLOWED LANDS.

The overflowed lands of Texas are not the property of the State. They are owned largely by private individuals. They lie in tracts of irregular shapes and varying sizes. These tracts usually contain both overflowed land and high land.

The natural fertility of the overflowed, or "bottom" lands is proverbial in Texas. While each flood supplements this fertility by adding to the land a thin layer of sediment, the floods are no longer necessary to the productiveness of the soil. On the contrary, the waters kill the growing plants, or destroy the matured crops. During periods when overflows do not occur, the annual yield is usually a bale of cotton to the acre.

The State laws authorizing the building of levees having been perfected only a short time, the major portion of the overflowed lands are unimproved and unprotected by levees. In this condition, their market value ranges from \$5.00 to \$25.00 per acre, according to the frequency and severity of the floods in the individual stream in question. The pro rata cost of building the highest levees rarely exceeds \$25.00 per acre. Assuming the maximum figures in both cases, the total cost of the land after the levees are built would be \$50.00 per acre.

Cotton lands that annually produce a bale to the acre are so far above the average, that it is difficult to reach a fair valuation for the overflowed lands, after they have been fully protected by levees; but in the few levee districts that are now completed, lands thus protected, are valued at not less than \$75.00 per acre. Considering their productiveness, this value is probably not at all excessive.

From the standpoint of the State, the financial advantage in reclaiming the overflowed lands results from the increase in the taxable values of the lands reclaimed. To encourage this development by means of a complete survey, the State seems abundantly justified, as the following figures will indicate. At the present time the unimproved overflowed lands are assessed for taxes at a valuation seldom exceeding \$10.00 per acre. After being protected from floods, this value no doubt could justly be raised to \$30.00 per acre. As the present total State tax rate is $26\frac{2}{3}$ cents per hundred dollars valuation, such an increase in assessments, brought about entirely by reclamation, would add to the State's revenue about $5\frac{1}{3}$ cents per year for every acre reclaimed. The total expense to the State in making the survey is never more than 20 cents per acre, and generally does not exceed 10 cents per acre. Consequently, within not more than four years after the levees are built, and more frequently within only two years thereafter, the State is entirely reimbursed for making the survey. This is the only expense incurred by the State in reclaiming the overflowed lands.

CHAPTER II.

THE CREATION OF THE STATE LEVEE AND DRAINAGE BOARD.

CO-OPERATIVE SURVEYS.

The State Levee and Drainage Board was created by act of the Thirty-first Legislature, approved March 19, 1909. Governor Thomas M. Campbell called the first meeting of the Board on July 6, 1909. At this meeting Arthur Alvord Sttiles of Travis county, Texas, then a topographer of the U. S. Geological Survey, and residing in Washington, D. C., was selected as State Levee and Drainage Commissioner.

The levee and drainage surveys of the Board were immediately instituted through a formal co-operative contract with the U. S. Geological Survey. This agreement, authorized by the act, and accomplished July 24, 1909, provided that the reclamation surveys should be made by the Federal bureau, the State designating the areas to be mapped, and paying one-half the cost of doing the work.

In selecting the general localities in which the first surveys were to be made, the Board, upon the suggestion of Attorney General Davidson, applied these practical tests: After field examination by the State Levee and Drainage Commissioner, is the area thought to be feasible of reclamation; have the communities taken steps to organize improvement districts, and does such organization appear practicable; are the surveys needed immediately? These underlying principles were also made a part of the co-operative agreement with the U. S. Geological Survey, and they have since grown to be the main factors upon which the State Levee and Drainage Board considers requests for new surveys.

As selected in this manner, the first areas surveyed are represented by the six topographic levee maps which accompany this report and which are fully described in a following chapter.

Under the co-operative agreement, precise levels and primary traverse lines were run along the East Fork of the Trinity River from Forney into Collin County; along the Little River from Valley Junction to Temple; and along both sides of the Brazos from Sealy to Waco. These lines were marked at intervals of about one mile, and a detailed description of the marks will be found herein under the heading of benchmarks.

Field work in co-operation with the Geological Survey continued until June, 1910, when the Board abandoned the joint survey for numerous reasons, of which the following are sufficient to mention.

The Geological Survey required that the territory being mapped should be divided into rectangular blocks about eight miles square, called "quadrangles," and that these blocks should be completely mapped. As the overflowed valleys are very irregular, and are generally not eight miles wide, this quadrangular system necessitated the expensive surveying and mapping of much territory in the hills, that had nothing to do with the reclamation work of the State, yet the Board was required to pay half the cost of doing the extra surveying. The cost of the co-operative work was further increased somewhat by inapplicable methods. The mapping

was not uniformly up to the usual standard of accuracy, and considerable remapping, correcting, and resurveying was therefore necessary.

When the co-operative survey was discontinued, the Commissioner, then employed as civil engineer to the Board, made the hydraulic measurements and computations, and worked out the levee plans for all of the areas that had been topographically mapped.

The results of the surveys made under the initial Act of 1909, being in the hands of the engravers at Washington, D. C., a brief report of progress was transmitted to the Governor by letter, dated December 31st, 1910.

The Act of 1909 appropriated $50,000.00. Of this amount $18,417.00 was spent for co-operative surveys with the U. S. Geological Survey. The sum of $1776.72 was expended for hydrographic surveys and office work done independently of the federal bureau, and the balance remaining, or $29,806.28, was reappropriated by the Act of 1911.

CHAPTER III.

THE WORK OF THE BOARD UNDER THE AMENDED LAW.

The law creating the State Levee and Drainage Board was amended by an Act of the Thirty-second Legislature approved March 20th, 1911. The amended law now in effect authorizes the necessary levee and drainage surveys to be made independently by the Board, or under co-operative contracts with other institutions, in the event the latter method subserves the best interests of the State. This law also authorizes a stipulated salary for the State Levee and Drainage Commissioner.

Under the provisions of the present law, the Commissioner secured the valuable assistance of the U. S. Department of Agriculture in the matter of drainage surveys in the coast country of Texas. A memorandum upon the subject was signed May 25th, 1911, by Mr. Charles G. Elliott, then Chief of the Bureau of Drainage Investigations. Agreeable to this order, drainage surveys were continued along the Rio Grande with Mr. W. N. Hall, Drainage Engineer, in charge. Headquarters were also opened in Houston with Mr. H. A. Kipp, Drainage Engineer, in charge. Under Mr. Kipp's direction, a drainage survey was made of Jefferson County. All of this work was done by the U. S. Department of Agriculture at government expense. Upon the grounds of co-operation, the State was not requested to contribute to the expense of the undertaking.

The greatest federal assistance to the State levee and drainage work is being given by the Corps of Engineers, U. S. Army. A resurvey of the Trinity River was authorized by Congress; and soon thereafter the Commissioner held numerous conferences with Major T. H. Jackson, Corps of Engineers, headquarters at Dallas, Texas, concerning the feasibility of co-operative surveys with the State Levee and Drainage Board. As a result of these conferences it became apparent that the work to be done by the War Department was, to a certain stage of development, identical with the requirements of the State in reclaiming the overflowed lands. On this account, and in courtesy to the State, it was decided to conduct the federal surveys, as far as possible, in a manner advantageous to the reclamation work of the State. With the approval of the Board, the Commissioner agreed to give, upon request of the federal department, such technical assistance as might be desired. Five surveying parties of the War Department are now in the field, extending primary traverse and precise leveling along the Trinity River from a point near Dallas, to tide water. The channel of the river is also being cross-sectioned at intervals of about every quarter mile; and more detailed cross-sections of both channel and valley are being taken every mile, throughout the entire length of the river, which is about 500 miles.

It would be impossible to intelligently plan a levee system for this river without the results of the survey now being made by the Corps of Engineers. If the work was not done by the federal government, it would ultimately have to be done by the State. As the methods being used by the War Department are practically the same as those in use by the State,

it is thought that the Trinity survey will cost the federal government about $75,000.00. The levee and drainage work of the State may, therefore, be regarded as having been benefited to this financial extent. The final results of the Trinity survey will probably be available during 1913.

The Commissioner also endeavored to secure for the State levee and drainage work the assistance of the U. S. Geological Survey. The annual appropriation for topographic surveys by this bureau is made by Congress in the form of a lump sum; and at the present time no definite system is employed in dividing the work among the several States. Upon any reasonable basis of division, Texas should annually receive a pro rata share of the topographic work amounting to about $20,000.00. As a matter of record, during the past sixteen years, the State has received from the Geological Survey in topographic surveys about $4000.00 per annum. The Commissioner prepared from the records a statement of these latter facts, and upon this basis requested of the Geological Survey an increase in the annual topographic allotment for Texas, with the added request that the federal surveys be made where they would be of the greatest practical value to the State in reclaiming the undrained and overflowed lands. The Geological Survey, however, declined to accede in any manner to the request of the department, unless the State should pay one-half of the expense of doing the work.

As practiced in the United States, contour topographical surveying and mapping is a branch of engineering that has been developed in the federal government mainly during the past fifteen years. It is an art not known in this State, and it is taught in only three of the larger universities of the United States. To secure topographic engineers from the federal government is not always feasible, and they cannot be had elsewhere. Upon the taking effect of the present law, the Commissioner was therefore forced to select men most qualified; and to train them in topographical engineering. At best, this is a slow and difficult task, but in the present instance, gratifying progress has been made. Less than one year ago the first topographic assistant was employed, and independent work was begun in the field. Since that time three engineers have become qualified in the various lines, with several other younger men now in training.

Notwithstanding the necessity of instructing a field force in the limited time mentioned, admirable progress has also been made in the topographic mapping of new areas. The Maysfield and Cameron sheets have been completed. The Holtzclaw Bridge sheet is almost completed, and the Dallas sheet will be completed in a very short time. Primary traverse lines and primary level lines have been extended along the Trinity River from a point about ten miles below Dallas to a point about twelve miles beyond Fort Worth. Much of this is double line, covering both sides of the river.

The levee maps of the new areas mentioned are not covered by this report, but will be published promptly upon completion. The new primary traverse line is 105.2 miles long. The new primary level line is 94.8 miles long. These lines are now finished, and the resulting benchmarks are described in tabulated form at the end of this report.

In view of the hardships, exposure, and attacks of malarial fever, which all of the new field employes have continually suffered as a natural

but unavoidable consequence to continued service during winter and summer, it is appropriate at this time to congratulate them upon their faithfulness to the work of the State; and to especially mention in this connection the three engineers, now at work, who have developed exceptional skill. These are: Dixon B. Penick, R. G. Tyler, and Ernest J. von Rosenberg.

The topographic mapping of this department is being done upon a larger scale than that employed by the U. S. Geological Survey during the recent co-operative work. The resulting maps are therefore much more accurate and detailed than those of the federal bureau. Hence it is difficult to compare the two types in point of output. Comparing them as to cost, it appears that, as done by the U. S. Geological Survey, topographic mapping costs the State more with government assistance than similar work of a higher quality costs without government assistance. The co-operative mapping cost the State 10 cents per acre. The more accurate mapping done independently by the Board costs 8½ cents per acre.

The primary traversing and primary leveling of this department is also of a higher order than that done by the Geological Survey. Compared to the work of that bureau, the lines being run by the Board are marked at almost twice as many points, and true meridians are permanently marked upon the ground. The State work costs somewhat less per mile than the work of the Geological Survey.

With the complete organization of the department, the recent purchase of the necessary technical instruments, and the continued training of the corps of assistants, it is reasonable to suppose that the reclamation surveys of the department will cost correspondingly less in the future than they have during the past year.

The Act of 1911 reappropriated $29,806.28 for the work, and also set apart an additional sum of $12,000.00 to be used if, in the discretion of the State Levee and Drainage Board, it was needed. Prior to August 31st of the present year, only $10,024.65 had been spent out of the first mentioned sum: and on account of the time required in organizing the department, the contingent item of $12,000.00 has not yet been needed.

CHAPTER IV.

THE SURVEY.

The Texas overflowed valleys being generally arranged in a series of distinct topographic and hydrographic divisions, each division constitutes the natural basis of a complete levee system, more or less dependent upon a similar system in each of the other divisions. It is seldom that one of these entire divisions is owned by a single individual; therefore, in every sense, levee protection is essentially a co-operative enterprise. Upon the same principle that the different interests within a single division are mutually protected, the different interests of adjacent divisions should also be mutually protected. Though the levees may be built one at a time, when all are finally completed, the several divisions in the valley throughout, should together form a continuous system in which there is the least danger of disastrous conflict. The department has endeavored to design the levees in a manner such that this result will ultimately be attained.

Such an extensive levee plan can be based only upon a most accurate and comprehensive survey, the field work of which may be said to begin in the immediate division that is to be leveed, from which locality it covers the other levee divisions adjacent. Naturally, a survey of this magnitude is not practical as a private work. It is little less feasible from a county standpoint. Obviously, it is a State undertaking.

The State views the levee problem from the head to the mouth of the river. The county is interested in the single division; and the private individual does not look beyond the boundaries of his own property. So. from the facts which only the survey can establish, the State desires this information: Will the new levee conform to the general system, and will it co-operate to the natural advantage of all the other divisions? The county requires to know: Is the individual enterprise feasible, and practicable; is it needed; will it be conducive of the public health; and is it a public benefit, and a public utility? But to the property owner the vital question is: Will the project pay him?

To answer all of these questions correctly, the survey must minutely establish the facts by showing, among other features, the following: The detailed topography of the divisions involved; the boundaries and acreage of each tract of land, showing in correct relative position the amount reclaimed, and the portion left unprotected; the high-water marks, and the flood limits; the maximum flood discharge of the main-stream, and of all the significant tributaries; the hydraulic gradients existing during flood stages, and likely to exist after the levees are built; the flood level that will result from building the levees; the necessary hydraulic capacity of floodways, canals and sluice-gates; the most practicable yet hydraulically correct position for the levee, its distance from the banks of the main channel, and from other levee positions, its curves and tangents, its height, grade, cross-section, slopes and cost.

The methods employed by the State Levee and Drainage Board in making the reclamation surveys have been modified, refined, and made

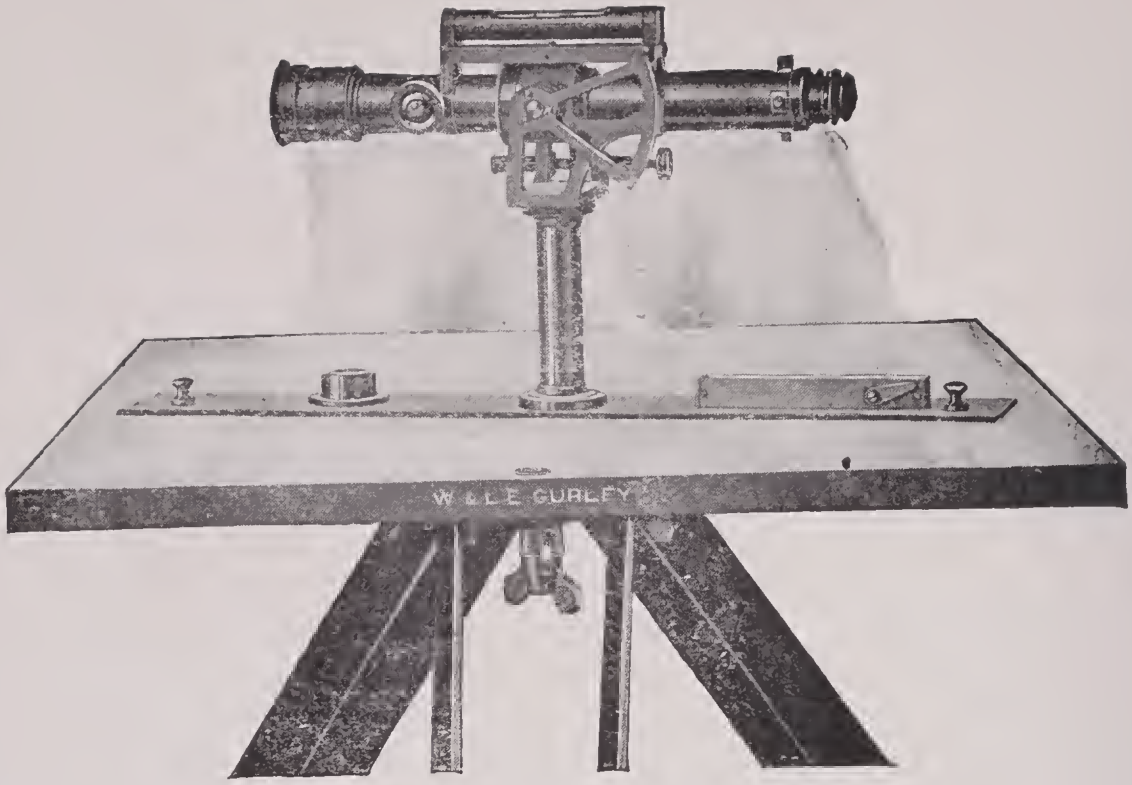
applicable to the special requirements; but in the main, they are similar to those originated and developed by the U. S. Geological Survey, during the past fifteen years.

The survey is separated into two general divisions, namely, topographic and hydrographic. The field work of the topographic division requires three distinct procedures. First, the determination of the latitude and longitude of certain definite, fixed points called "benchmarks." This resulting basic information is called "horizontal control." Second, the determination of the precise elevation above sea level of the same or independent benchmarks. This data is called "vertical control." Third, the construction of the topographic map upon which all auxiliary features are held in correct relative position, or are "controlled" by the two mentioned types of benchmarks.

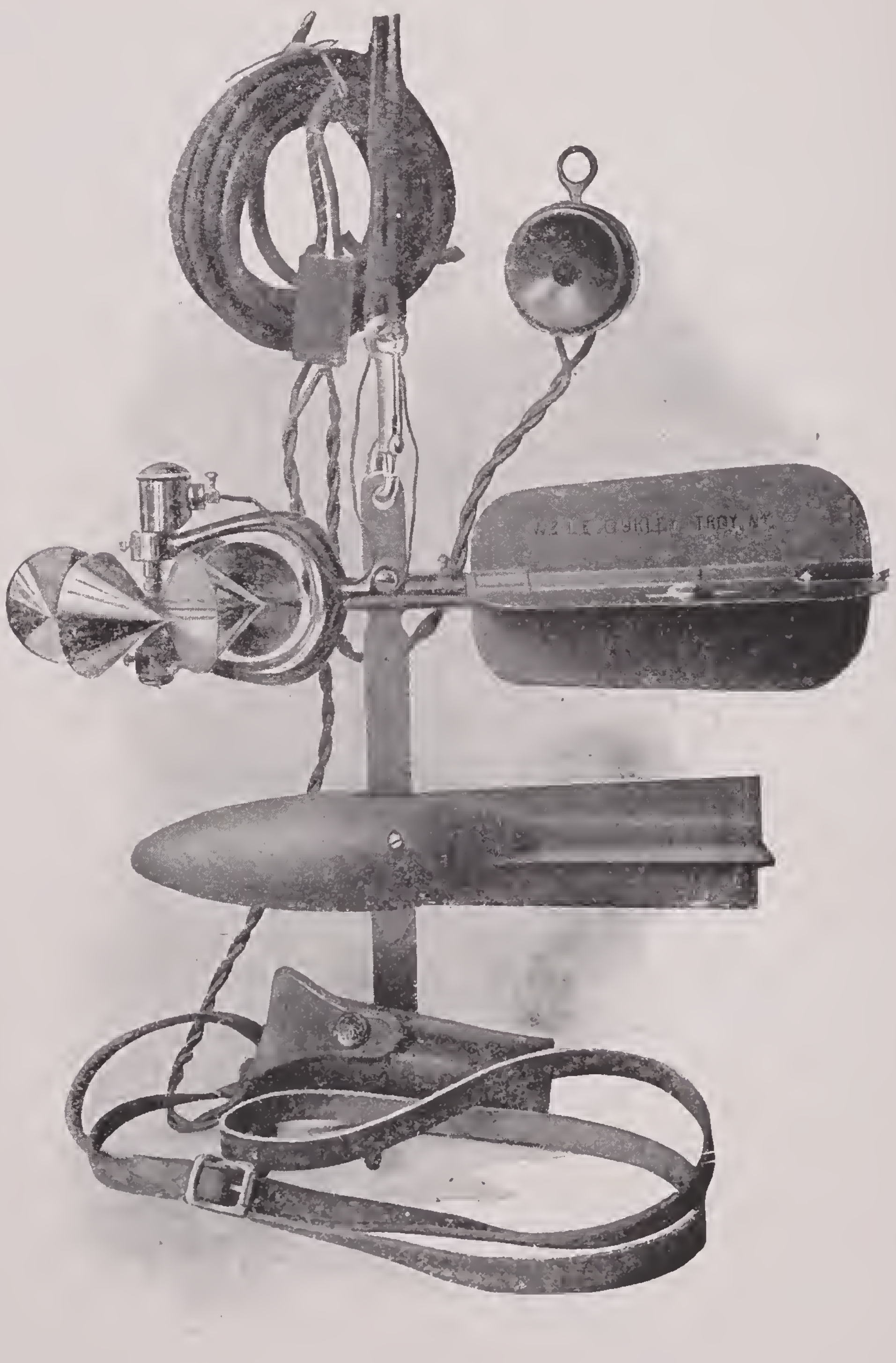
The uniform system used in the survey of the public lands of the United States does not obtain in Texas. There are no standard and accurate section corners from which detailed field measurements may reliably be made. The only geographic locations of this nature are the triangulation stations of the various federal bureaus, contained in systems which barely reach the eastern quarter of the State, and in which known points are seldom closer together than twenty miles. In States where the public land system is available, the section and township lines are frequently regarded as adequate horizontal control for the average reclamation maps. There being no such reference points in Texas, however, some dependable form of horizontal control is absolutely essential.

The horizontal control for the reclamation maps of this department is obtained by means of an accurate and effective process called "primary traverse." This is a system of measurements extended in a continuous line from a geodetic point previously established by triangulation or astronomy, to a similar point of closing; or the traverse is returned as a closed circuit to end upon its point of beginning. The line takes the most convenient course, but as a rule, approximately follows a central route through the flood-plain.

The traverse line is permanently marked at intervals of about one mile, with a heavy iron post benchmark, usually set at points that are locally well known throughout the countryside. These posts are four inches in diameter, and four feet long. They are placed firmly in the ground and permitted to project about six inches above the surface. The bottom of the post has a ten-inch flange which retards settling, and prevents the benchmark from being easily pulled up. The center of a bronze cap on each post marks the precise point of latitude, longitude, and elevation; and the figures representing these values are stamped by hand thereon. The cap bears the seal of the State, and a notice of the law which provides a penalty for willfully disturbing the benchmark. Other marks of a more temporary nature are set about every quarter mile, and numerous significant objects are also established, or "cut in" by secondary triangulation from the traverse line. The benchmarks have nothing whatever to do with the final position of the levees or other improvements. They are for the use of the engineers in making the survey. At intervals of about seven miles, and if possible on a county road, or near a church or schoolhouse, the true north is staked out upon the ground, by means of two benchmark posts, placed about fifteen hun-



The Johnson Plane-Table, and the Telescopic Alidade. U. S. Geological survey pattern. (Manufactured by W. and L. E. Gurley, Troy, New York.)



The Price Current Meter (electric)—Manufactured by W. and L. E. Gurley, Troy, New York.

dred feet apart. From these two posts the correct declination of the compass needle may be determined at any time during the levee work. Incidentally the true meridian is thereafter available to county surveyors and the public generally.

In primary traversing, the horizontal angles are measured with an engineer's transit of high order, reading to 30″, equipped with a full vertical circle, and stadia wires. The distances are measured with a 300-foot steel tape, held horizontally, and placed under a 12-pound tension. All distances measured with the tape are recorded by each tapeman. The transitman with the stadia also reads every distance and records it in a separate notebook. This is a precaution against such gross blunders on the part of the tapeman, as the forgetting of a tape length or a plus distance. The true azimuths are obtained from observations upon the star Polaris, at or near elongation. Observatory time is daily secured from Washington, D. C., by courtesy of the Western Union Telegraph Company. The position of the star is computed from astronomical tables furnished by the various federal bureaus. The convergence of meridians is indicated by the observed azimuths, and is proportionately applied as a correction to the instrumental plain azimuths. The latitude and longitude of each mark on the line is then computed from the well-known formulæ.

The primary traverse circuits recently completed by this department have closed with a probable error of 1 in 6160, or a little less than 10 inches in a mile. The average cost of the traverse work has been about $10.50 per mile.

The vertical control follows the primary traverse line, and all traverse benchmarks are further utilized for elevation marks. This type of work is called "primary leveling." The instrument used is a 22-inch Y-level, equipped with stadia wires. The rod is of the New York type, and the Geological Survey pattern. While in use the level is protected from the direct rays of the sun by means of a large umbrella held over it by an assistant. In this way errors resulting from unequal expansion are eliminated. Actual work is suspended during high winds and when the air is "boiling." Lengths of fore and back sights are equalized to avoid accumulation of instrumental error, and the effect of the earth's curvature. In order to secure accuracy on turning points, a steel pin, carried by the rodman for the purpose, is driven into the ground each time, and the rod is set upon the head of the pin. The rod is held truly vertical by means of plumbing levels. Both levelman and rodman are required to keep the level notes; and after each sight, the figures in the final results are compared to prevent numerical errors. The limit of accumulative error set by the U. S. Geological Survey in this class of leveling is expressed by the formula $.05\sqrt{\text{distance in miles}}$. For example, an error of one-half foot vertically is allowable for 100 miles of line. All of the primary leveling recently done by this department, however, has checked well within this limit of error. The average speed has been about 4 miles per day; the average cost about $5.50 per mile.

The topographic mapping is done with the plane-table. This is a field instrument eminently suited to its purpose. It is essentially a tripod with an adjustable head, to which a drawing board is attached. To this board is secured, with thumb-screws, a plane-table field sheet of heavy

map drawing paper which does not permanently change in size when exposed to the weather. Upon this sheet the map is made bit by bit, day by day, out in the open country. When the topographer has covered the area, the mapping has covered the paper. With the plane-table, there are no office computations from surveyors' notes, and no map blunders from that productive source.

A separate part of the plane-table consists of a telescope mounted upon a heavy metal plate which serves as a ruler or straight edge. This instrument is the "alidade." When the tripod legs have been firmly set in the ground, the alidade is placed upon the drawing board, and is operated from any point on the plane-table sheet. The alidade contains the stadia wires, the level, and the compass-needle. It, therefore, measures distance difference of elevation, and direction. With the alidade, the plane-table is placed "square with the world," or "oriented"; and is then made rigid by a clamp on the tripod head.

The plane-table mapping of the overflowed valley begins with the construction of a "polyconic" geographical projection upon a plane-table field sheet representing the area that is to be mapped. The sheet is designated by the name of the most important topographic feature that comes within the area; such, for example, as the "Rockwall Sheet." By means of their geodetic co-ordinates, the controlling benchmarks are carefully platted upon the projection. From these benchmark positions, the mapping progresses until all of the significant features of the area are located; and with contour lines are delineated in their correct relative sizes and shapes, or by appropriate symbols are indicated in their correct positions, and the complete topographic map is finished.

The principal hydraulic field measurements necessary in the levee surveys are made to determine the maximum discharge of the streams. This quantity is expressed in "second-feet," and is obtained by multiplying the number of square feet in the cross-section of the stream by the mean velocity of the current in feet per second. The water surface fixes the size of the cross-section, and as the area is measured in the usual manner, the only significant part of the problem is the determination of the mean velocity. This may be done in the three following ways:

When a flood is actually passing in a stream, the measurement is quite a simple matter. A section of the stream as long as possible, is selected where the channel and flood-way are comparatively straight, and reasonably uniform. About the middle of the section a cross-section is selected. The water surface is carefully marked, and the area of the cross-section in square feet is subsequently determined. The actual velocities of the water in feet per second are then measured with a modern current meter, preferably of the electric type. The meter is lowered into the water at intervals of about ten feet along the cross-section, and is read twice at each interval: once at a point about .2 of the depth below the water surface, and once at about .8 below it. The mean velocity of each 10-foot vertical section is the average of the two meter readings. The discharge of each vertical section is the product of this average velocity by the area of the vertical section. The sum of these several products is the total discharge of the stream; which, divided by the area of the entire cross-section, gives the mean velocity of the stream.

If the stream is too swift or too deep to admit of wading, the meter

Topographers at work with the plane-table.
(Photos by von Rosenberg.)

Topographers at work with the plane-table.
(Photos by Buchanan)

may be operated from a bridge, a cable-way, a ferry boat, or a captive skiff. The depths at which the meter is lowered into the water will be indicated upon the graduated rod or cable that suspends the meter. The horizontal intervals at which it is lowered may be marked upon a bridge rail, upon a rope or wire stretched across the stream, or established by any other convenient means.

The surface velocity of the stream can also be reliably calculated by using floats of any convenient type, not likely to be affected by the wind. A comparatively straight base 200 to 400 feet long, extending an equal distance upstream and downstream from the cross-section, is laid off along the bank and marked at both ends. A float is placed in the middle of the stream sufficiently far above the upstream end of the base that the float may adjust itself to the current before it reaches the first mark. The time required for the float to traverse the measured base is noted in seconds. To avoid error, a number of floats are observed in this way, and an average period of time is obtained. The number representing the length of the base in feet, divided by the number representing the average time in seconds, gives the average surface velocity in feet per second. The surface velocity multiplied by the coefficient .8 gives the mean velocity of the stream, and should fairly check the value obtained with the meter. If the stream is large, the surface velocity should be determined at several equal transverse intervals. The mean of the surface velocities found at these intervals represents approximately the mean surface velocity, which is then reduced to the mean velocity, as above stated.

In levee work, it is generally necessary to know the maximum discharge of the stream during the highest floods of record, but naturally the opportunity of actually measuring one of these is a rare occasion. If the high-water level of the highest flood can be obtained at a cross-section where two or three of the lesser floods have been actually measured, the maximum discharge of the stream during the highest flood of record may be closely approximated. This is accomplished by a rectangular graphic proportion, in which a horizontal scale reading from left to right along the bottom edge of the diagram is made to represent discharges in second feet, and another scale reading from bottom to top on the left-hand vertical side of the diagram is made to represent gauge heights, as indicated by the high-water level. The zero of both scales is the lower left-hand corner of the diagram. The discharges of the several lesser floods that have been actually measured are laid off upon the horizontal scale, and their corresponding gauge heights upon the vertical scale. In the case of each flood, the intersection of a vertical line from the horizontal scale with a horizontal line from the vertical scale indicates a point upon what is called the "discharge curve," which, beginning at zero, will be found to pass upward, and to the right over the diagram. The several floods actually measured, when platted in this manner, will determine the general course of the discharge curve. A horizontal line from the gauge height representing the highest water of record may then be drawn to intersect this discharge curve, extended. From this point of intersection a vertical line is dropped to the discharge scale, and the maximum discharge of the highest flood of record is indicated by the scale. The discharge curve should be extended with caution. If the shape and size of the cross-

section changes materially between the highest flood actually measured, and the highest flood of record, the estimated maximum discharge will not be reliably indicated.

The velocity of the current of a stream may also be theoretically determined by Kutter's Formula. This well-known formula is employed when the stream has ceased to flow; or when at ordinary stage it is desired to ascertain the rate of speed that the water assumed in the stream during flood stage. As a rule in Texas, flood velocities are most conveniently measured theoretically where the various railroads cross the overflowed valleys. Such crossings frequently contain long sections of trestlework. Kutter's Formula would be of the greatest assistance if it could be used to ascertain the velocity of flood waters passing through this piling, but experience shows that it does not altogether apply under such circumstances. By actual tests with the current meter, this department is now endeavoring to develop a modification to the regular formula that will make it more applicable to these trestle cross-sections. The results of these experiments will be given in a subsequent publication.

As generally used, Kutter's Formula is as follows:

$$\textit{Mean Velocity} = \left\{ \frac{\dfrac{1.811}{n} + 41.65 + \dfrac{.00281}{s}}{1 + \left\{ 41.65 + \dfrac{.00281}{s} \right\} \dfrac{n}{\sqrt{r}}} \right\} \sqrt{rs}$$

Where r=the hydraulic radius; s=the slope of the water surface; and n=a numerical value designed to represent the physical condition of the water course. Pending experiments now being made in the Texas streams, the value .035 has been assumed as the coefficient of n. Under usual conditions, it is thought that the formula gives fairly reliable results.

In applying Kutter's Formula, a straight and uniform section of the stream is selected, and a cross-section taken about the middle of the section, as already described. The upper boundary of the cross-section is the straight line representing the water surface. The lower boundary of the cross-section is the profile of all the submerged ground surface; and this is also the "wetted perimeter." The area of the cross-section in square feet divided by the length of the wetted perimeter in feet gives the hydraulic radius, r. The hydraulic slope is indicated by a water mark located upstream from the cross-section, and by a similar one located downstream from the cross-section. The value s is obtained by dividing the difference in elevation between the two water marks, by the distance between them. Substituting in the formula the appropriate numerical values for these several terms, the resulting theoretical mean velocity is deduced.

Aside from making velocity measurements of actual floods, the hydraulic surveying of this department is usually deferred until the completion of the topographic mapping. Theoretical hydraulic investigations are then much simplified, and many of the problems may be solved directly from the complete data shown upon the topographic field sheets.

Stream gauging with the current meter. The dots in the cross-section indicate positions of the meter while being read. (*Courtesy of the U. S. Geological Survey.*)

After the completion of the entire survey, made in the manner described, the necessary levee and drainage systems are designed upon the field sheets, from which preliminary profiles and estimates are also made. The co-ordinates of points on these graphic locations are obtained from the topographic map, and the positions of the improvements, with such minor modifications as may be permissible, desirable, or necessary, are then marked out upon the ground.

CHAPTER V.

LEVEE LOCATION, HEIGHT AND GRADE.

It is a well-known characteristic of the overflowed river valleys that the ground surface, rising gradually from the base of the foot-hills at either side of the flood-plain, reaches its greatest elevation at the banks of the channel overlooking the principal stream. Hence, a levee to be of minimum height and maximum protection should be built along this crest, but a stable position cannot be obtained so near the channel, and the distance which should separate the proposed levee from the adjacent stream bank may be regarded as the result of a compromise between practical interests, and other more technical requirements, now to be discussed.

The case is selected for illustration where a protection levee is required upon each of the opposite sides of the stream channel. As a first requirement, obviously a flood-way or clear space large enough to convey the entire flood volume, must be provided between the opposite levees. The fixed factor of this flood-way is the maximum discharge of the stream, during the highest flood against which the proposed levees are designed as a protection. The adjustable factors are the heights and positions of the proposed levees, or the two dimensions sought. As previously explained, it follows conversely that the maximum discharge of the stream divided by the mean velocity of the flood, gives the cross-sectional area of the required flood-way. The area of the cross-section of the channel being established by nature, it remains to increase or diminish the heights of the opposite levees, and the distance between them, until the proper supplemental area in the flood-way cross-section is found.

The simplest manner of finding this area is by a series of computations, using trial positions and heights for the levees. For this purpose a cross-section of the proposed flood-way may be considered at any point desired. As represented in Figure 1, the anticipated flood level is the surface of the maximum flood, raised somewhat by reason of the levees. A trial elevation of this flood level with a trial distance separating the opposite levees, is assumed. Not being uniform throughout, the cross-section must be treated in three sections. The middle section represents the stream channel; the two end sections, BC and FG, represent the spaces between the channel banks and the levees. Usually, there is no reason to know with safe accuracy the actual mean velocity of each of the three sections. The separate mean velocities must, therefore, be theoretically calculated by applying Kutter's Formula, as previously explained. The wetted perimeter of the channel cross-section is the line CDEF; that of the end sections is the ground surface, BC and FG, and the submerged sides of the levees. The vertical distances, CX and FY, from the channel banks to the flood surface are not counted as part of the wetted perimeter. The hydraulic slope s and the coefficient of roughness n are the same for all parts of the cross-section.

Having computed the mean velocity and maximum discharge of each section of the cross-section, the total maximum discharge through the entire cross-section is obtained by adding these three results. Comparing

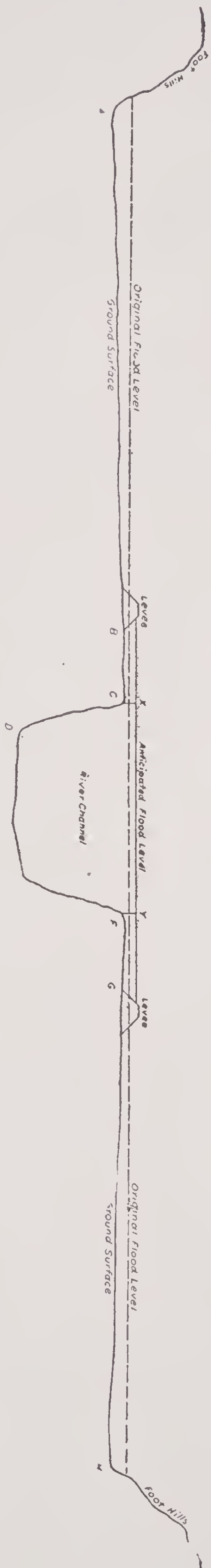


Figure 1.

Ideal cross-section of overflowed river valley illustrating characteristic ground surface slope, determination of hydraulic capacity of flood-way, resulting flood level, and position of levees.

this maximum discharge with the known maximum discharge of the stream, the area of the cross-section with the assumed positions and heights of the levees is shown to be correct, or too great or too small. If not correct, another trial computation is made with the assumed values changed in the direction last indicated, and the correct dimensions are soon found.

It will be noticed that an increase of a few inches in the elevation of the high-water level in the flood-way is equivalent to an increase of a hundred feet or more in the distance between the levees and the channel banks. But great care must be exercised in raising this level. The "regimen," or usual system of the stream, changes as the flood level rises. Sudden and disastrous alterations may take place in the channel; or existing levees further upstream may be overtopped by the resulting backwater. This department is making investigations in the Texas rivers to ascertain, if possible, more specifically where the hydraulic danger point lies in this vertical direction. Pending additional information, the practice of materially raising the flood level has been avoided; and in the work of the department thus far, it has not been found necessary even in extreme cases to raise it more than two feet.

In addition to the foregoing requirements of a flood-way of adequate hydraulic capacity, the distance between the proposed levee and the bank of the channel is further governed by the following features of a more local nature; namely, stability of base foundation; dangers resulting from caving banks; the necessity of sufficient space for properly formed borrow pits and bermes; and the danger of current wash.

Surface and cut-bank examination of the streams that have been surveyed by this department indicate an excellent quality of soil for levee building. Sand deposits, bogs, and other faults are rare; and in the few cases where difficulties of this kind have been observed, the trouble is effectively obviated by slightly shifting the preliminary position of the proposed levee.

Naturally, the danger from caving banks may be regarded with little more anxiety. Compared with many streams successfully leveed long ago, the banks of the Trinity, Brazos, and Little River, do not cave to any alarming extent. In the well-defined places where caving does take place, it is evident that the caving stops when the bend reaches a certain limit of sharpness. Furthermore, in the present condition of the river, the caving is gradual, and seldom begins until the waters are subsiding. This fact is so well recognized along the Brazos that to the experienced resident, the sound of falling banks is the sign of falling floods. These caving banks, however, are obviously the points of some danger, and must be dealt with upon individual merit. Probably some time will elapse before the cost of artificial revetment along these rivers will be justified. Yet in many places nature, unaided, seems to attempt a revetment with thickets of quick-growing trees. Following this natural indication, doubtless much can be done to check and perhaps altogether stop the caving in places where, in the intervals between floods, a thick forefront of willows and cottonwoods could be planted and protected until well grown. But this procedure, while well deserving of trial, is more or less superficial. At the present time the only positive precaution is that of locating the levee at a safe distance from the caving bank. Along

the streams mentioned in this report such a distance ranges from 200 to 300 feet; and may be more specifically determined after careful observations and study of the peculiarities of the individual stream in the section involved, where the remaining portions of formerly straight and continuous fence lines, roads, ridges, and other topographic features, or historical facts are available as evidence of the progress and extent of bank caving.

The space required for a properly formed and located borrow pit is dependent upon the size of the levee that is to be built. As the earth must be taken only from the side of the levee adjacent to the stream channel, the dimensions of the borrow pit may be had from Table I, using the height and crown of the proposed levee as arguments. This space must also be sufficient to provide for a berme at the toe of the levee, and another undisturbed strip of land between the outer edge of the borrow pit and the channel. The berme is usually twenty feet wide, and the distance from the borrow pit to the channel should, in general, not be less than 100 feet.

The dangers to the levee position which result from current wash may be seen from Figure 2. In the illustrative case presented, the greatest velocity exists near the center and upper portion of the cross-section. From this point the dangerous velocities decrease in the direction of the channel banks, and disappear between the banks and the levee positions. Experiments are now in progress by this department which, it is hoped, will result in a more accurate determination, in the Texas streams, of the nature of these side currents, and the risk to the levees which may result therefrom. In consideration of this type of hydraulic danger, the levees along the Brazos, Little River, and Trinity have not been located nearer to the adjacent channel bank than 250 feet, this distance being indicated by data at present available.

The grade along the top of the levee must obviously be parallel to the surface of the highest flood that is expected to be held back by the levee. The proper difference of water level existing at any two points on the levee, divided by the distance between the two points, clearly established this grade. If no difference in water level is found between the two points, the levee is supporting back water, the grade is zero, and the top of the levee is level. If the levee is retreating from the main stream, and following the up-grade course of a tributary stream, to join the high land, the grade of the levee adopts the grade of the side stream, plus an increasing height due to the back water curve. The surface slopes of all floods are by no means parallel. In the Texas streams, the great flood of 1899 gives a generally uniform longitudinal surface profile; whereas, the smaller ones present rather unaccountable wave effect. As a basis for levee grades, the surface slope of the water at lowest stage is scarcely more reliable than the slope indicated by the high-water marks. The safest hydraulic datum to which the top of the levees may be built parallel, is the water surface in the channel of the stream adjacent to the levees, as determined during the highest available stage of the stream, but after all evidence of disturbance has disappeared and the condition of the stream is stationary. As a precaution against the possible erratic behavior of the flood volume, the levees, having been established upon

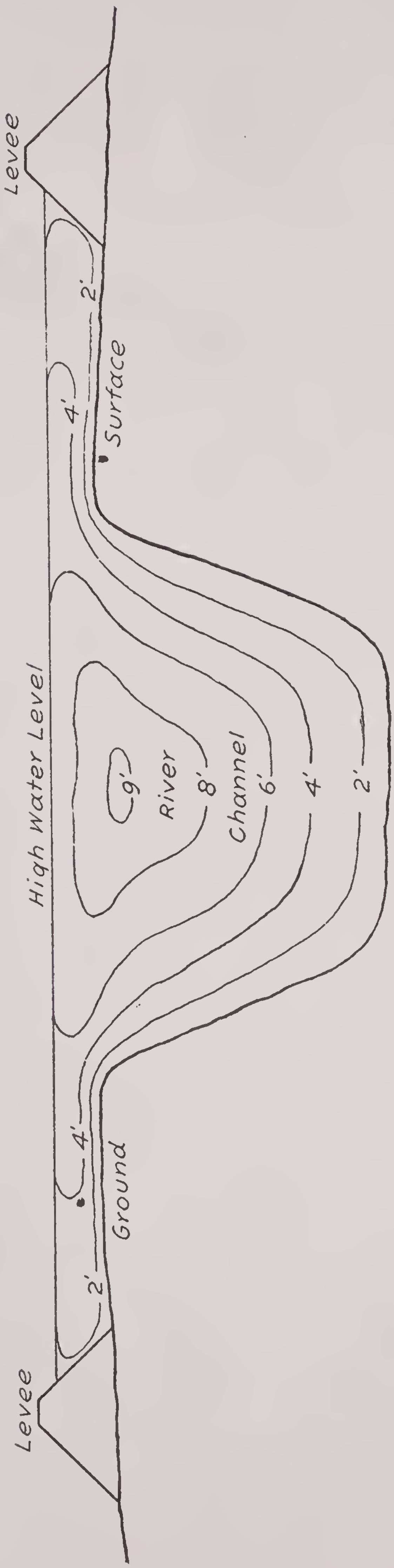


Figure 2.

Typical cross-section of river channel, showing probable distribution of current velocities, in feet per second, and their influence upon levee positions.

this grade, are then built two feet higher than the level of the anticipated high-water.

Under primeval conditions a flood, spread out over an unprotected valley, moves along its course in the form of a lower volume, and an upper volume; and the two are frequently in conflict. The lower volume fills the meandering main channel of the stream, and extends directly upward to the high-water surface, except in places where the upper volume is sufficiently powerful to sweep across it, causing a sub-surface deflection. In which case there is a stratum where the water is not moving. The upper flood volume covers the flood-plain. When the levees are built parallel to the channel, the original condition of the upper volume of the flood is eliminated; all of the waters are required to follow the main channel; and the hydraulic slope indicated by the original high-water marks no longer exists. The movement of the flood in its original condition, no doubt, is greatly retarded by the presence of this upper flood volume, and the resulting cross-currents.

In a flood-plain where the main stream channel meanders extensively, the original high-water slopes, and those that are expected to exist after the levees are built, sometimes lead to singular combinations that require considerable investigation and study. Certain characteristics of the original flood surface slope as a whole, may therefore, be observed. This slope is not necessarily the same throughout, as the slope of the average ground surface beneath it. A line of equal elevation passing through a high-water mark is generally normal to the longitudinal axis of the valley. The surface of the flood does not always fall in the direction that all of the flood travels; consequently a paradoxical situation takes place among the original high-water marks, when they are considered solely in relation to the meandering stream channel. Following down the natural flow of the channel, along the bank of a bend that has meandered half-way around, a high-water mark located not far from the channel upstream, is lower than a similar mark further downstream; and the contradictory condition continues until the channel resumes the direction of the moving flood surface.

It will be seen that the foregoing process for finding a suitable position for the levee has the effect of determining a series of points along the proposed route through which the levee must be built. With these points thus established, the levee alignment must not under any circumstances consist of tangents and angles. There must be no angles. The stream does not employ angles in any part of its length; and as already shown, the levees, to avoid cross-currents must follow with moderate precision, the meanderings of the stream. The straight portions of the levee must be connected by curves. From a hydraulic standpoint, a circular curve is the least desirable, but a curved connection which reaches its greatest abruptness at the lower end, furnishes the maximum protection against washing along the outer levee. In bends of the channel so sharp that it is not feasible to levee around them, and where there may be severe cross-currents, a single dyke, or spur levee should be built from the main levee at the upper end of the bend to a position well within the point of the bend. In this manner the great flood volume is safely turned by the aid of its natural channel; and does not encounter disturbances when leaving the levee system at the upper point, or returning to it at the next lower point, but moves serenely along a natural and consistent grade.

CHAPTER VI.

CUTTING BENDS—CHANNEL IMPROVEMENT.

As a simple means of lessening the floods in the overflowed river valleys, the first impulse of the casual observer is to shorten the channel by cutting the bends. This is far from being a simple means. The primary effect of shortening the channel is to increase the natural established grade of the stream. The direct result of such a change is usually to cause the stream to begin anew its adjustment between channel and grade, which may mean bank caving, shoaling, the overtopping of levees, and other serious damage more difficult of forecast. In actual experience, it has universally been observed that, briefly, the cutting of bends whereby the established grade is materially increased will lower the overflow for a distance above the cutting, but will very much raise the flood level in the immediate sections downstream. This fact alone is sufficient to justify the most cautious procedure, if not altogether to prohibit the shortening of such bends.

On the other hand, it is sometimes necessary to change the position of part of a stream by duplicating or even shortening certain bends of the channel in order to facilitate levee building. The established grade, of course, may be actually preserved in the duplicated bend; and in the shortened bend, the change may be comparatively so insignificant or so isolated that the increase in the grade is practically eliminated by the effect of the back water.

The cutting of bends to facilitate drainage through channels having insufficient grade is altogether another problem. In this case the established grade is regarded as an elastic feature, and may be brought to the required (but safe) degree of steepness by shortening certain bends.

In all navigable streams, however, permission to cut the bends must be obtained from the Secretary of War.

Removing the timber and brush from the stream channel is equivalent to slightly enlarging the cross-section of the channel. By this method the carrying capacity of the stream in the improved section may be increased practically without danger, simply because the efficiency of the improvement is small. If this were not the case the resulting effect of the clearing in the lower end of the cleared section would, in a measure, be similar to the effects resulting from cutting the bends. By clearing a comparatively long section of the stream, the flood capacity of the channel will be increased about ten per cent. In disconnected sections of the channel the cost of the improvement is barely justified. If the entire length of the stream could be cleared, there would be a much greater increase in the capacity of the channel. Great care should be taken not to remove timber growth that has the effect of protecting banks that otherwise would be in danger of caving by current wash. In several localities of the State, it has been observed by this department that there is a local practice of dumping tree tops and underbrush into the stream channel in order to dispose of this waste material. As a

natural consequence in many places, rafts and earth deposits have formed to such an extent that the channel is practically obliterated, and the floods immediately pass out into the valley. If these valleys are to be protected by levees, this practice should be discontinued, and the rafts already formed should be burned out as rapidly as possible during the dry season.

CHAPTER VII.

SLUICE-GATES AND SYPHONS.

A sluice-gate is an automatic or hand operated valve contrivance designed to furnish a passage-way through the levee for local drainage. It is built into the levee and forms part of the embankment. When there is no flood, the sluice-gate stands open, permitting the drainage from within the district to pass into the main river. When a flood occurs in the main river, the gate is closed and thereby prevents the water from backing into the district. Automatic sluice-gates are not recommended.

All sluice-gates depend for their successful operation upon the double assumption that a flood in the interior drainage seldom occurs simultaneously with a flood in the main river; and that, should such a condition arise, the flood from the interior drainage would do no material damage to the district. Continuing this reasoning, the question is sometimes reached as to what kind of water the district would prefer to be drowned with. Consequently installing sluice-gates upon large tributary drainage should be avoided by continuing the levee to high land. In the districts shown upon the topographic maps, all large drains have been deflected in this way; but in some localities the topographic conditions are such that large sluice-gates must be relied upon, otherwise levee protection under the particular circumstances would not be a feasible undertaking. To meet these special conditions, a large reinforced concrete sluice-gate has been designed, and is illustrated in Figure 3.

One of the chief objections to a sluice-gate of any type is the difficulty with which a permanent union can be secured between the earth composing the levee, and the material of which the sluice-gate is made. The tendency of the earth to shrink away from the sluice-gate is greatest during dry weather. At this time, numerous crevices occur around the sluice-gate in positions difficult to reach, even if always discernible. This is an obstacle that is removed by using syphons instead of sluice-gates. The syphon, as illustrated in Figure 4, is an iron pipe that does not cut the levee anywhere, but passes completely over the top of it. The principle of this device is well understood. With the valves of the syphon closed, the air is first exhausted by means of the hand pump. Upon opening the valves, the water flows upward through the pipe, over the top of levee, and discharges at the lower level, outside of the district. The valves are again closed by hand when a flood in the river rises against the levee, and reverses the water level. The syphon is especially suited to conveying limited drainage of continuous flow. It is universally in use along the Mississippi levees. The syphon shown in the illustration is made in many different sizes, by the Murphy Iron Works of New Orleans.

An effective screen must be provided at all sluice-gates and syphons to prevent their becoming clogged by drift wood, brush, stalks or trash. Such material may be arrested by building a wire net fence around the improvements at some distance away. A second and finer screen should

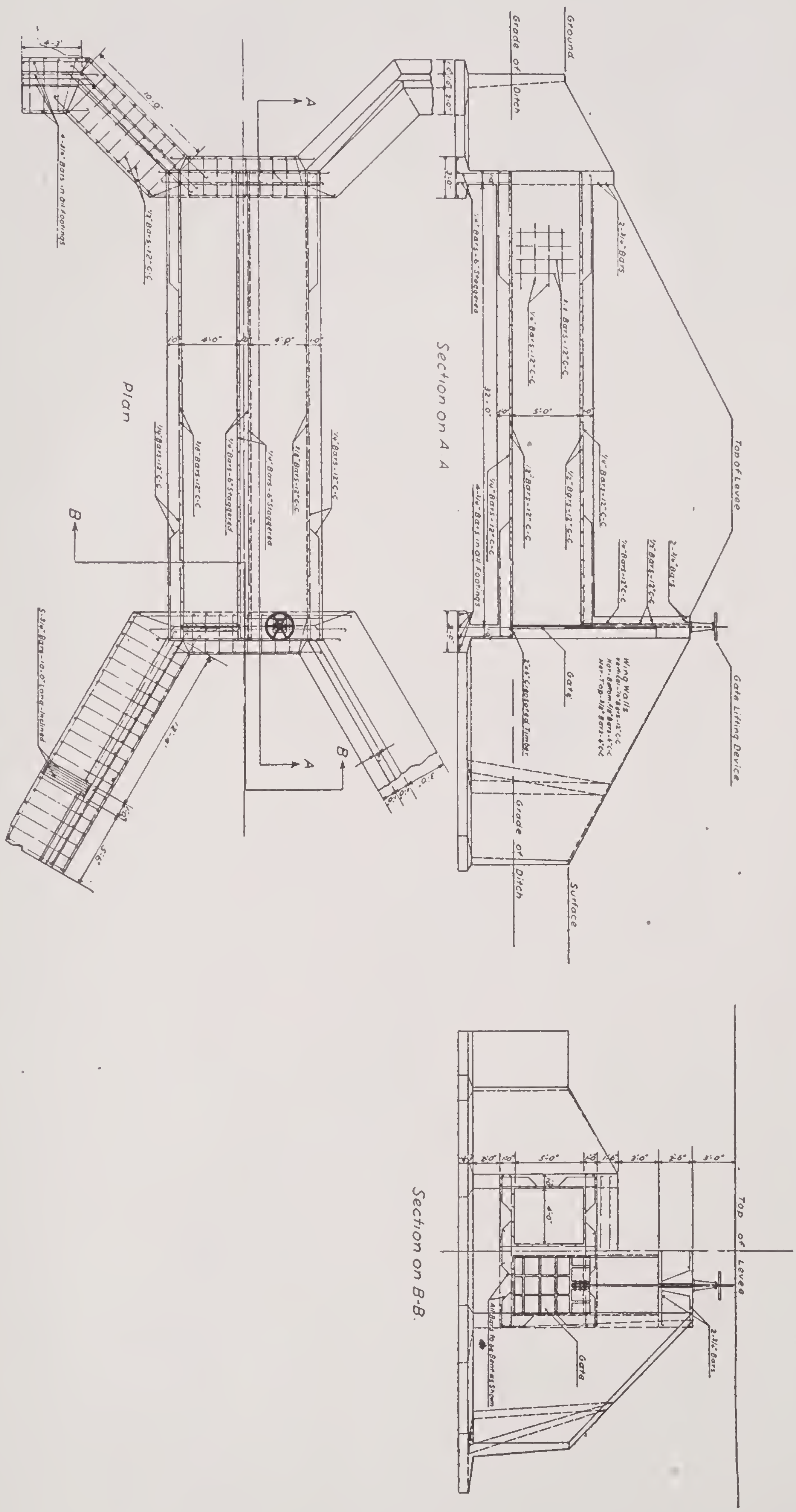


Figure 3.
Reinforced Concrete Sluice-Gate for discharging local drainage through the levee.
(Designed by R. G. Tyler, 1912. J. K. Duke, Draftsman.)

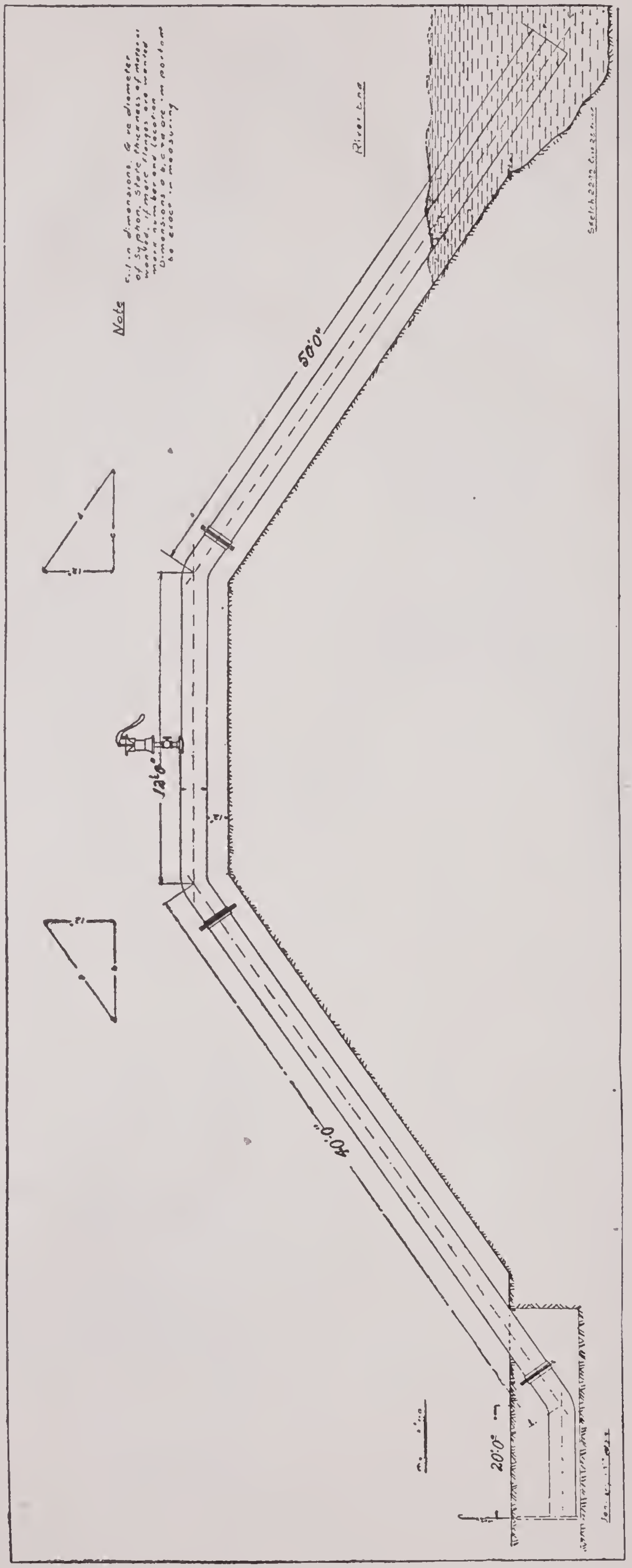


Figure 4.
Syphon for discharging local drainage over the top of the levee. (Manufactured by the Murphy Iron Works of New Orleans, La.)

also be placed across the immediate opening in the sluice-gate or syphon.

The sizes of the necessary sluice-gates and syphons may be ascertained from the maximum discharge of the drain passing through them, by applying a modification of Kutter's Formula, in a manner similar to that described for finding the size of a flood-way.

CHAPTER VIII.

THE LEVEE MAPS ACCOMPANYING THIS REPORT.

The six complete topographic levee maps which accompany this report are, the Rockwall and Barnes Bridge Sheets, which together represent a section of the valley of the East Fork of the Trinity River in parts of Collin, Rockwall, Dallas, and Kaufman Counties; the Buckholts Sheet, which shows a portion of the valley of Little River in Milam County; and the Millican, Washington, and Howth Sheets, which cover the Brazos Valley in parts of the Counties of Washington, Waller, Grimes and Burleson.

These maps represent a total overflowed area of 101,077 acres. Of this area 70 per cent can be permanently protected from floods equivalent to that of 1908, at a general average cost of $13.08 per acre.

In total length, the six sheets show 210 miles of levees.

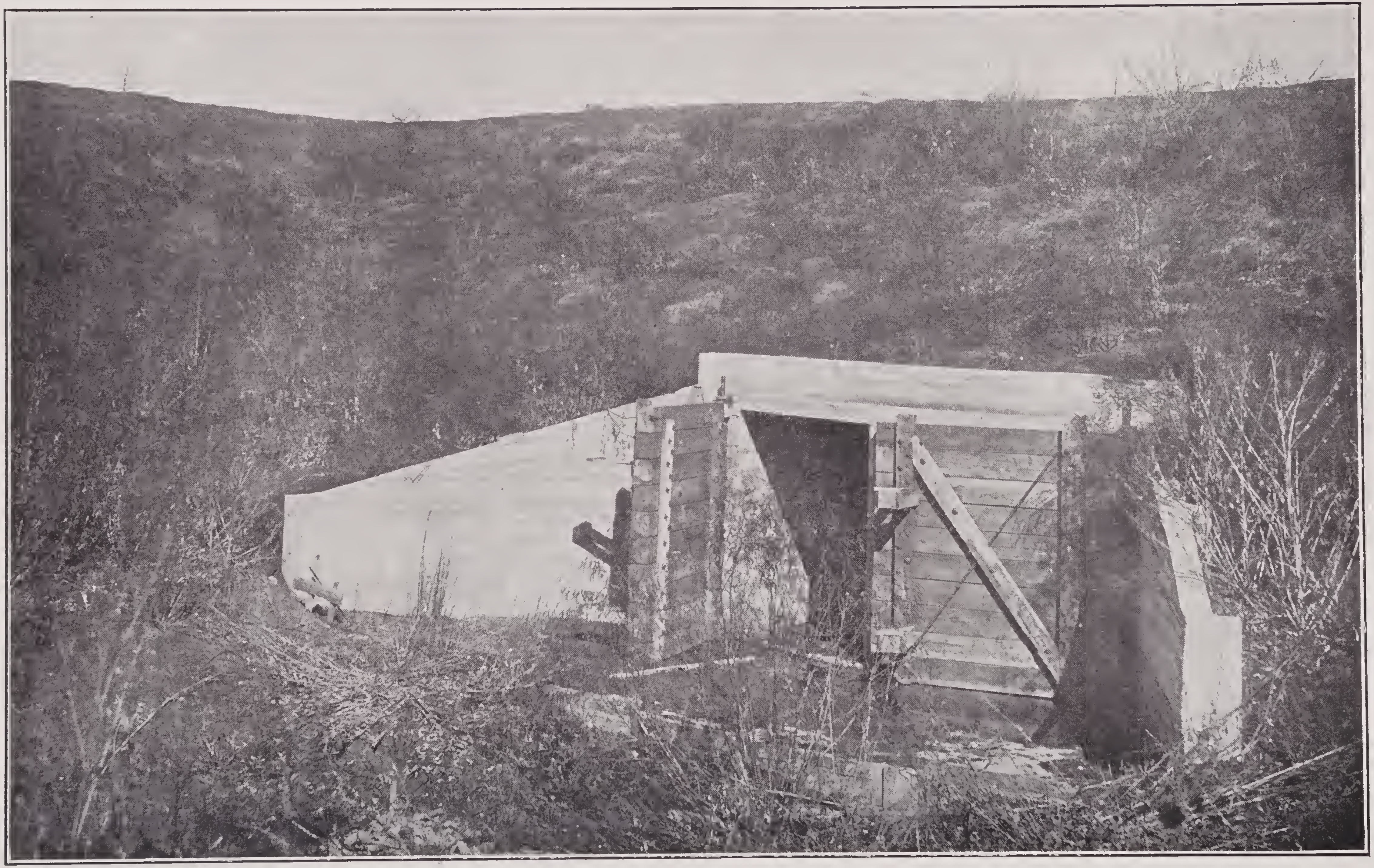
The average heights of the levees, the preliminary estimates of yardage and cost; and the acreage in each levee division shown upon the six above mentioned sheets will be found in tabulated form elsewhere in this report. These estimates do not include the cost of right-of-way, clearing, or grubbing.

The preliminary profiles of all of the levees are available and will be furnished to county and district officers when needed.

The topographic mapping was done by the U. S. Geological Survey in co-operation with the State of Texas. By the co-operative agreement, the original field sheets became the property of the federal bureau, but the maps were reproduced by photographic transfer to copper plates, and the plates were engraved by hand. Transfers from the copper plates were then placed upon lithographic limestone, and 500 copies of each of the six original maps were printed for the State. A second edition of the maps may be printed at small cost at any time, from the engraved copper plates now in the possession of this department. The total cost of engraving and printing the first 3000 edition of the maps was less than the State would have had to pay an expert draftsman to reproduce by hand, only four copies of each map. The copper plates constitute a practically indestructible record of the difficult and expensive topographic work. This is the method of map reproduction developed, and now in use by the U. S. Geological Survey.

The Legend, a column of symbols printed upon the margin of each map fully explains every feature of the map.

A black print of the entire quadrangle, as mapped by the U. S. Geological Survey, accompanies each topographic levee map; and is intended as a general guide to the territory not shown upon the engraved sheets.



Sluice gate in the levee of Washington County District Number 1, near Chapel Hill, Texas.

CHAPTER IX.

INDIVIDUAL LEVEE DIVISIONS.

The levee divisions shown upon the topographic maps are numbered consecutively, and to each number is added the first letter of the name denoting the sheet upon which the division is located. A division falling partly on two sheets is designated by the initials of each of the sheets.

Two types of levees have been adopted: a levee of standard height, and one of secondary height. The standard levee is designed to be sufficiently high to hold back the waters of the greatest flood of record. The secondary levee would be submerged by such a flood, but would furnish protection against a flood of ordinary proportions. The secondary levee is recommended only where the cost of a standard levee may not be justified.

The highest flood of record occurred in the Brazos River in July, 1899. This flood was so much higher than the next highest one, which occurred in 1908, that the standard levee for this river has been designed in two heights, one for each of these two floods. The position and alignment of the two types of levees are the same, the only difference being in point of size and height. Hence, the smaller levee may at any time be raised to the size required for the flood of 1899 by simply building it to the necessary grade and cross-section. The secondary levees indicated on the Brazos Sheets are to have the uniform, arbitrary, height of five feet. Those on all of the other sheets are to be four feet high.

After the maps were transmitted for engraving, it was decided to partially change two of the levee divisions. The levee in the first division on the Howth Sheet (H-1) was relocated to follow the meanderings of the river channel. The levee in the second division on the Millican Sheet (M-2) was turned at a point three hundred feet north of mile-mark 12 (12+300) and run northwestward parallel to the H. & T. C. R. R., to join the high land. The profile sheets show these levees in the corrected positions.

The third levee division on the Buckholts Sheet (B-3) presents a number of difficult features. The valley at this point is comparatively narrow. The local drainage from the watershed on the north is extensive. The course of the river channel is unusually winding, and the natural hydraulic grade is steep. If a number of the channel bends could be cut, the levee building would be greatly facilitated; but for reasons already discussed, and without regard to the legal phase of the case, cutting the bends cannot be recommended. These difficulties apply even more forcibly to any project to change the course of the entire river by turning it through the Cut-Off Slough.

The levee design for division Buckholts-3, as given upon the topographic map is far from perfection, but at the present time it appears more feasible than the other two plans to be discussed. The levee indicated upon the map closes upon itself at mile-mark 13. At this point the flood waters would be divided by the proposed levee, the larger portion passing along the main channel of the stream, and the remainder

going out behind the levee, down the bed of Cut-Off Slough. The main channel would thus be relieved to this extent. It is known that the natural behavior of the river is after this manner, without reference to a proposal to confine it with levees. Usually there is little gained by dividing a flood volume; but in the present case, the Cut-Off Slough being a natural by-pass, the original flood level will not be raised by the levee, and the lowest possible embankment will be all sufficient. It will be seen that the only part of the levee requiring standard height, is the short section between mile-marks 13 and 2, and this portion should be of maximum height in any levee plan adopted. The required levee around the district, downstream from these two mile-marks, can therefore, be built at minimum cost. At the same time, this advantage is partially offset by the excessive length of the right-of-way, and the fact that lands along the Cut-Off Slough are necessarily left unprotected. The hydraulic grade in Cut-Off Slough is very steep, but in time of flood, the water in the by-pass will be very shallow, and no danger to the levee is expected on account of a current too swift. The levee position along the by-pass has been removed a considerable distance back from the foot-hills in view of this feature of the situation. As planned, the levee will not materially upset the conditions in the river. For that reason it does not seem probable that, as a result of the improvement, the river will "swap" to the bed of the by-pass in Cut-Off Slough.

A second plan for levee protection in division Buckholts-3 contemplates joining the levee from mile-mark 13 to the foot-hills near T. B. M. 378.2, thus closing the by-pass through Cut-Off Slough. Following around the main channel of the river from this junction at the foot-hills, the levee would return upstream along Cut-Off Slough to a point near mile-mark $11+\frac{1}{2}$. At this point the levee would reach a sufficient elevation to shut off the backwater from the river, and the local drainage would come out between the returned end of the levee and the foot-hills at the lower end of the district. Compared to the levee design printed upon the topographic map, this plan would save the building of about one and one-half miles of levee (or the section between mile-marks 13 and $11+\frac{1}{2}$). But since the entire flood would be forced to pass around the winding course of the river, practically all of the levee would require the standard height. The short section of levee saved would not compensate for the increased height of the remaining portion. However, a small additional amount of land would be protected from the floods of the river.

As a third plan for protecting this district, the levee may be built in all respects similar to the arrangement described in the preceding paragraph, except that from a point just above mile-mark $9+\frac{1}{2}$ the embankment should run directly to the nearest part of the foot-hills, closing upon the high ground near B. M. 361.1. The side drainage would be taken out through a sluice-gate in the vicinity of this benchmark. Though a levee built in this way would require the standard height throughout, it would protect about 20 per cent more property than any other system suggested. The plan highly recommends itself upon these grounds only. While a sluice-gate would cost much less than the section of levee which it would eliminate, the maximum discharge of the side

drains at this point is very large, and there is some question as to the feasibility of successfully conveying it through a sluice-gate.

The levee plans of the many other divisions shown upon the topographic maps are comparatively simple and require no detailed explanations. All necessary data concerning them may be had from the maps, the table of estimates, and the profile sheets.

CHAPTER X.

LEVEE BUILDING AND MAINTENANCE.

A levee is a simple embankment of clean, homogeneous earth taken or "borrowed" from the side next the river.

The size of a levee is determined by the width of the top or "crown"; by the vertical height, and by the slopes of both sides. From these dimensions the width of the base may be obtained.

The "borrow pit" is formed in removing the earth out of which the levee is built. It is separated from the levee by a strip of undisturbed land called the "berme," which must be left at the toe of the levee, and across which the earth from the borrow pit is hauled upon being deposited to make the levee. The borrow pit must not form a continuous ditch along the edge of the berme, but must be broken at intervals of about three hundred feet by additional strips of undisturbed land called "traverses." The traverses should be about twenty feet wide. They connect the berme with the undisturbed land lying off toward the bank of the river. The earth for building, must not be taken from the "land side" of the levee. The size of the borrow pit corresponding to a levee of a given size will be found from Table I. The recommended shape of the borrow pit, and the positions of the borrow pit and berme with relation to the position of the levee, will be seen from Figure 5.

For purposes of exploration, in sections where the quality of the levee foundation is unknown or suspected, a ditch about three feet deep and of the same or convenient width should be dug along the center of the levee base before building is attempted. This is called a "muck ditch." By it, any covered logs, isolated sand and gravel deposits, or other features of local false foundation can be detected and removed, or the levee position can be shifted in order to avoid them. Defects of this nature, located more than three feet below the levee base, and therefore left undiscovered by the muck ditch are usually not serious; but care should be exercised in this regard and the exploratory excavations should be made deeper in sections where trouble of the kind may exist.

Before building is begun, the base of the levee must be carefully cleared and grubbed, and thoroughly cleaned of all vegetable matter. Where the borrow pit is to be, the ground surface must also be thoroughly cleaned off so that tree roots, stumps, sand or gravel will not be taken into the body of the levee. Immediately before building, the base of the levee must be plowed deep and fine, in order to secure the best possible union, or "bond," between the base surface and the earth composing the levee. The muck ditch is also a material aid in obtaining this bond.

Both side slopes of all levees are recommended to be not steeper than two to one.

At present the simplest, and possibly the cheapest method of levee building is with mules and scrapers, especially where such equipment belonging to the plantations composing the district can be utilized for levee building during seasons when not otherwise employed. No doubt, however, some especially designed type of excavating machinery can be

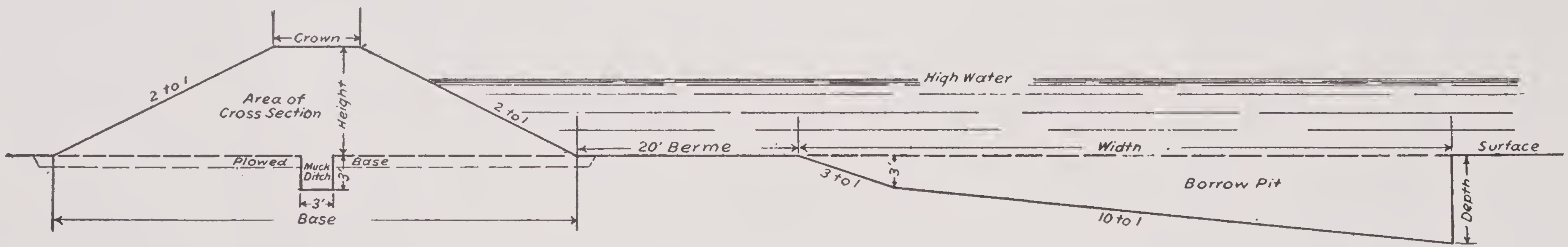


Figure 5.

Showing relative position of levee, muck ditch, berme and borrow pit.

developed with which the levee may be built at even a lower cost. During the dry season, the soil of the average overflowed valley can be handled with ease. Investigations upon the subject of levee building machinery applicable to the Texas conditions are now in progress by this department.

By any building method employed, the earth composing the levee must be deposited in horizontal layers. When so deposited, it does not require artificial settling of any kind, and the volume may be expected to shrink about ten per cent.

All local drainage must be away from the levee; and each of the series of borrow pits, formed by the intervening traverses, must be drained directly into the river. If stagnant water is allowed to remain near the levee, it may saturate the levee base or embankment, and in Texas such water invites crawfish that dig holes in the levee; and encourages burrowing animals.

When the levees have been built up to the grades given in the profile sheets, and, with an allowance for shrinkage, they have been finally dressed off, the entire embankment, the berme, and a strip of land along the inner side of the levee must promptly be set to Bermuda Grass. No other vegetation must be allowed to grow upon the levees.

In Texas, the greatest damage to the levees results from season cracks during midsummer and fall. A careful examination of this difficulty has been made throughout the State during the past three years. In some localities these dry-weather crevices become very severe, at times extending completely through the levee, and into the ground beneath. But actual experience shows that the trouble can be entirely prevented, by pasturing stock upon the levee. For this purpose, the levee and about thirty feet of the right-of-way on either side must be fenced; and the stock permitted to graze at liberty in the enclosure thus formed. The stock should be turned into the enclosure at the beginning of the dry season, and allowed to remain as long as necessary. The levee may be used as a pasture whenever needed as such, but no stock should be allowed within the enclosure during wet weather. If the levee has been built with side slopes not steeper than two to one, and it has become thoroughly sodded with Bermuda Grass, the moderate grazing of stock will in no wise injure the embankment. Practical experience along the lines mentioned will soon indicate how the levee may be kept in most excellent condition.

If, through carelessness, a levee has become completely honeycombed with season cracks, it should be thoroughly cleaned of all vegetation, and then deeply plowed all over, from top to bottom. The ground surface should also be plowed for a space of ten to twenty feet on both sides of the levee. After being again brought up to grade, the levee should be smoothed off, and as soon as possible sodded to Bermuda Grass.

A well-travelled road upon the top of a levee will also entirely prevent season cracks. Where this has been the practice, the levees have remained in perfect condition. The method, however, opens a broad field of possibilities. Unless the embankment has been especially constructed, the roadway must be absolutely abandoned in wet weather, to avoid injuring the levee. At precisely this time perhaps the road is most needed; and difficult complications result.

Levee embankment prior to being sodded with Bermuda grass. Milam County Levee District Number 1, near Cameron, Texas.

Preliminary Estimates of Levees—Average Heights, Yardage, and Cost.

Rockwall Sheet.

Designation of Levee Division	By Mile Sections: Between mile-marks	Average height of levee	Amount of material in section	Cost of section at 15c per cubic yard	By Levee Divisions: Total over-flowed area	Total cost at 15c per cubic yard	Cost of re-clamation per acre
		Feet	*Cubic yards*		*Acres*		
R-7 (Incomplete)	0–1	7.7	32228	$4,834.20			
	1–1.9	7.9	29634	4,445.10	353.2	$9,279.30	$26.27
R-6 (Incomplete)	0–1	5.5	18265	2,739.75			
	1–2	7.6	31524	4,728.60			
	2–2.3	7.8	9879	1,481.85	486.5	8,950.20	18.40
R-5	0–1	3.7	7081	1,062.15			
	1–2	9.3	48380	7,257.00			
	2–3	8.2	35904	5,385.60			
	3–4	7.9	33675	5,051.25			
	4–4.3	4.2	2362	354.30	795.2	19,110.30	24.03
R-4	0–1	5.5	6027	904.05			
	1–2	8.8	40597	6,089.55			
	2–3	8.5	38211	5,731.65			
	3–4	8.4	37468	5,620.20			
	4–4.7	6.8	17452	2,617.80	781.7	20,963 25	26.82
R-3	0–1	8.1	33403	5,010.45			
	1–2	9.5	50140	7,521.00			
	2–2.4	9.3	16933	2,539.95	602.4	15,071.40	25.02
R-2	0–1	7.7	30616	4,592.40			
	1–2	8.8	40597	6,089.55			
	2–3	9.2	47481	7,122.15			
	3–4	10.2	56633	8,494.95			
	4–5	10.5	59527	8,929.05			
	5–6	9.8	52878	7,931.70			
	6–6.3	3.9	2735	410.25	2344.0	43,570.05	18.45
R-1 (Secondary)	0–1.2	4.0	10951	1,642.65	104.0	1,642.65	15.79
R-9 (Secondary)	0–1	4.0	10404	1,560.60	78.0	1,560.60	20.01
R-10 (Secondary)	0–1.3	4.0	13689	2,053.35	131.0	2,053.35	15.67
R-11 (Secondary)	0–1.1	4.0	12046	1,806.90	92.0	1,806.90	19.64
R-12 (Secondary)	0–1.3	4.0	13908	2,086.20	143.0	2,086.20	14.59
R-13 (Secondary)	0–0.7	4.0	7666	1,149.90	51.0	1,149.90	22.55
R-14 (Secondary)	0–1.2	4.0	13470	2,020.50	70.0	2,020.50	28.86
R-15 (Secondary)	0–0.9	4.0	9308	1,396.20	63.0	1,396.20	22.16
R-16 (Secondary)	0–1	4.0	7118	1,067.70	65.0	1,067.70	16.43
R-17 (Secondary)	0–0.9	4.0	9527	1,429.05	46.0	1,429.05	31.07
R-18 (Secondary)	0–0.7	4.0	7994	1,199.10	48.0	1,199.10	24.98
R-19 (Secondary)	0–0.9	4.0	10185	1,527.75	83.0	1,527.75	18.40
B-R-1	0–1	8.1	35161	5,274.15			
	1–2	7.9	33675	5,051.25			
	2–3	8.9	41419	6,212.85			
	3–4	6.5	24132	3,619.80			
	4–5	6.6	24796	3,719.40			

Preliminary Estimates of Levees—A verage Heights, Yardage, and Cost—Continued.
Rockwall Sheet—Continued.

Designation of Levee Division	By Mile Sections				By Levee Divisions		
	Between mile-marks	Average height of levee	Amount of material in section	Cost of section at 15c per cubic yard	Total over-flowed area	Total cost at 15c per cubic yard	Cost of re-clamation per acre
		Feet	*Cubic yards*		*Acres*		
B-R-1 (Continued)	5–6	4.9	15136	$2,270.40			
	6–7	5.3	2065	309.75	1913.0	$26,457.60	$13.83
B-R-2	0–1	9.0	45760	6,864.00			
	1–2	9.2	47481	7,122.15			
	2–3	7.9	31991	4,798.65	865.5	18,784.80	21.70
B-R-3	0–1	9.2	47481	7,122.15			
	1–2	8.8	40597	6,089.55			
	2–3	9.6	51079	7,661.85			
	3–3.8	8.8	32478	4,871.70	1812.5	25,745.25	14.20
Total for Rockwall sheet					10928.0	$206,872.05	$18.93

Barnes Bridge Sheet.

Designation of Levee Division	Between mile-marks	Average height of levee	Amount of material in section	Cost of section at 15c per cubic yard	Total over-flowed area	Total cost at 15c per cubic yard	Cost of re-clamation per acre
B-R-4 (Secondary)	0–1.4	4.0	15331	$2,299.65	131.4	$2,299.65	$17.50
BB-12 (Secondary)	0–1	4.0	10294	1,544.10			
	1–1.9	4.0	10075	1,511.25	298.5	3,055.35	10.23
BB-11 (Secondary)	0–1	4.0	10513	1,576.59	45.3	1,576.95	34.80
BB-10 (Secondary)	0–1	3.8	9687	1,453.05			
	1–2	4.2	11812	1,771.80			
	2–2.2	3.9	1263	189.45	252.4	3,414.30	13.53
BB-9 (Secondary)	0–1.2	4.0	12922	1,938.30	93.4	1,938.30	20.75
BB-8 (Secondary)	0–1	3.6	9308	1,396.20			
	1–2	4.4	12750	1,912.50			
	2–3	3.9	10521	1,578.15			
	3–3.2	1.5	146	21.90	438.7	4,908.75	11.19
BB-7	0–1.1	7.8	35237	5,285.55	135.6	5,285.55	38.98
BB-6	0–1	5.3	16693	2,503.95			
	1–2	7.9	33675	5,051.25			
	2–2.6	3.8	5449	817.35	354.3	8,372.55	23.63
BB-5	0–1	7.5	27395	4,109.25			
	1–2.1	8.3	37420	5,613.00	267.6	9,722.25	36.33
BB-4	0–1	8.8	38567	5,785.05			
	1–2	8.4	37429	5,614.35			
	2–3	9.2	47481	7,122.15			
	3–4	11.1	65550	9,832.50			
	4–5	8.3	36686	5,502.90			
	5–5.5	2.7	1385	207.75	1894.6	34,064.70	17.98
BB-3	0.1	9.8	52878	7,931.70			
	1–2	10.1	55694	8,354.10			
	2–3	10.7	61522	9,228.30			
	3–3.3	5.7	4268	640.20	588.1	26,154.30	44.47
BB-2	0–1	5.8	17354	2,603.10			
	1–2	10.7	61522	9,228.30			
	2–3	10.6	60505	9,075.75			
	3–4	11.0	64533	9,679.95			
	4–5	9.1	46621	6,993.15			
	5–6	4.1	7853	1,177.95	1618.5	38,758.20	23.95
BB-1	0–1	10.2	54934	8,240.10			
	1–2	10.7	61522	9,228.30			
	2–3	10.3	57611	8,641.65			
	3–4	8.2	35904	5,385.60			
	4–4.7	2.8	3675	551.25	1008.7	32.046.90	31.77
Total for Barnes Bridge sheet					7127.1	$171,597.39	$24.08

Preliminary Estimates of Levees—Average Heights, Yardage, and Cost—Continued.

Buckholts Sheet.

Designation of Levee Division	By Mile Sections: Between mile-marks	Average height of levee	Amount of material in section	Cost of section at 15c per cubic yard	By Levee Divisions: Total over-flowed area	Total cost at 15c per cubic yard	Cost of re-clama-tion per acre
		Feet	*Cubic yards*		*Acres*		
B-6	0–1	6.2	22293	$3,343.95			
	1–2	7.0	27378	4,106.70			
	2–3	8.6	38994	5,849.10			
	3–4	7.8	32932	4,939.80			
	4–4.4	4.7	5224	783.60	987.9	$19,023.15	$19.26
B-5	0–1	7.4	30077	4,511.55			
	1–2	8.6	38994	5,849.10			
	2–2.2	9.9	10763	1,614.45	416.0	11,975.10	28.79
B-4	0–1	8.4	37429	5,614.35			
	1–2	8.9	41419	6,212.85			
	2–3	8.1	35161	5.274.15			
	3–4	6.8	26048	3,907.20			
	4–5	8.3	36686	5,502.90			
	5–6	7.4	30077	4,511.55			
	6–6.9	2.4	3355	503.25	2752.1	31,526.25	11.46
B-3	13–1	8.8	40597	6,089.55			
	1–2	6.4	23506	3,525.90			
	2–3	5.5	18265	2,739.75			
	3–4	6.3	22880	3,432.00			
	4–5	6.0	21120	3,168.00			
	5–6	3.7	9700	1,455.00			
	6–7	5.6	18812	2,821.80			
	7–8	4.6	13650	2,047.50			
	8–9	7.0	27378	4,106.70			
	9–10	5.9	20533	3,079.95			
	10–11	9.5	50141	7,521.15			
	11–12	9.4	49280	7,392.00			
	12–13	7.6	31524	4,728.60	2600.4	52,107.90	20.04
B-2 (Secondary)	0–1.4	4.0	14893	2,233.95	126.5	2,233.95	17.66
B-1 (Secondary)	0–1	4.3	12281	1,842.15			
	1–2	3.6	9308	1,396.20			
	2–2.2	5.2	3832	574.80	306.4	3,813.15	12.44
Total for Buckholts sheet					7189.3	$120,679.50	$16.79

Millican Sheet—Flood of 1908.

Designation of Levee Division	Between mile-marks	Average height of levee	Amount of material in section	Cost of section at 15c per cubic yard	Total over-flowed area	Total cost at 15c per cubic yard	Cost of re-clama-tion per acre
M-S-1	0–1	10.7	61522	$9,228 30			
	1–2	9.1	46621	6,993.15			
	2–3	11.3	67623	10,143.45			
	3–4	12.1	76189	11,428.35			
	4–5	10.0	54756	8,213.40			
	5–6	10.6	60505	9,075.75	5102.1	$55,082.40	$10.80
M-1	0–1	2.9	6688	1,003.20			
	1–2	12.3	78379	11,756.85			
	2–3	6.0	21120	3,168.00			
	3–3.6	7.1	17387	2,608.05	954.8	18,536.10	19.41
M-2	0–1	9.1	46621	6,993.15			
	1–2	8.0	34418	5,162.70			
	2–3	9.2	47481	7,122.15			
	3–4	11.5	69696	10,454.40			
	4–5	7.8	32932	4,939.80			
	5–6	7.4	30077	4,511.55			
	6–7	7.0	27378	4,106.70			
	7–8	8.5	38211	5,731.75			
	8–9	9.8	52878	7,931.70			
	9–10	10.0	54756	8,213.40			
	10–11	9.1	46621	6,993.15			
	11–12	5.1	16153	2,422.95			
	12–13	7.1	28043	4,206.45			
	13–13.1	3.6	558	83.70	9487.7	78,873.55	8.31
Total for Millican sheet (1908)					15544.6	$152,492.05	$9.81

Preliminary Estimates of Levees—Average Heights, Yardage, and Cost—Continued.

Millican Sheet—Flood of 1899.

Designation of Levee Division	By Mile Sections: Between mile-marks	Average height of levee	Amount of material in section	Cost of section at 15c per cubic yard	By Levee Divisions: Total over-flowed area	Total cost at 15c per cubic yard	Cost of re-clama-tion per acre
		Feet	*Cubic yards*		*Acres*		
M-S-1	0–1	14.4	103645	$15,546.75			
	1–2	12.9	85262	12,789.30			
	2–3	15.0	111467	16,720.05			
	3–4	15.8	122340	18,351 00			
	4–5	14.0	98560	14,784.00			
	5–6	14.8	108807	16,321.05	5102.1	$94.512.15	$18.52
M-1	0–1	6.6	24796	3,719.40			
	1–2	16.4	137280	20,592.00			
	2–3	11.1	65550	9,832.50			
	3–3.6	13.4	56548	8,482.20	954.8	42,626.10	44.64
M-2	0–1	12.5	80647	12,097.05			
	1–2	11.3	67623	10,143.45			
	2–3	12.7	82955	12,443.25			
	3–4	15.4	116864	17,529.60			
	4–5	12.4	79513	11,926.95			
	5–6	12.8	84089	12,613.35			
	6–7	15.1	112797	16,919.55			
	7–8	14.8	108807	16,321.05			
	8–9	16.1	132861	19,929.15			
	9–10	16.3	135794	20,369.10			
	10–11	15.4	116864	17,529.60			
	11–12	11.5	69696	10,454.40			
	12–13	13.4	91207	13,681.05			
	13–13.1	9.9	3229	484.35	9487.7	192,441.90	20.28
Total for Millican Sheet (1899)					15544.6	$329,580.15	$21.20

Washington Sheet—Flood of 1908.

Designation of Levee Division	Between mile-marks	Average height of levee	Amount of material in section	Cost of section at 15c per cubic yard	Total over-flowed area	Total cost at 15c per cubic yard	Cost of re-clama-tion per acre
W-3	0–1	2.2	4147	$ 622.05			
	1–2	3.2	7744	1,161.60			
	2–3	7.1	28043	4,206.45			
	3–4	9.4	49280	7,392.00			
	4–5	5.9	20533	3,079.95			
	5–6	6.9	26713	4,006.95			
	6–7	6.2	22293	3,343.95			
	7–8	6.4	23506	3,525.90			
	8–9	5.8	19947	2,992.05			
	9–10	8.4	4121	618.15			
	9–10	6.8	7814	1,172.10	6451.9	$32,121.15	$4.98
W-2 (Secondary)	0–1	4.6	13650	$2,047.50			
	1–2	5.3	17209	2,581.35			
	2–2.2	8.2	7181	1,077.15	478.8	5,706.00	11.92
W-1	0–1	8.3	34118	5,117.70			
	1–2	6.8	26048	3,907.20			
	2–3	6.6	24796	3,719.40			
	3–4	6.3	22880	3,432 00			
	4–5	7.0	27378	4,106.70			
	5–6	5.8	19947	2,991.05			
	6–7	7.6	31524	4,728.60			
	7–8	9.6	51079	7,661.85			
	8–9	10.8	62500	9,375.00			
	9–9.8	11.0	61306	9,195.90	4664.0	54,235.40	11.63
H-W-1	0–1	6.9	26713	4,006.95			
	1–2	7.6	31524	4,728.60			
	2–3	6.5	24132	3,619.80			
	3–4	5.7	19399	2,909.85			
	4–5	3.6	9308	1,396.20			
	5–6	6.6	24796	3,719.40			
	6–7	6.8	26048	3,907.20			
	7–7.9	3.5	7847	1,177.05	3088.3	25,465.05	8.25
Total for Washington sheet (1908)					14683.0	$117,527.60	$8.00

Preliminary Estimates of Levees—Average Heights, Yardage, and Cost—Continued.

Washington Sheet—Flood of 1899.

Designation of Levee Division	By Mile Sections				By Levee Divisions		
	Between mile-marks	Average height of levee	Amount of material in section	Cost of section at 15c per cubic yard	Total over-flowed area	Total cost at 15c per cubic yard	Cost of re-clamation per acre
		Feet	*Cubic yards*		*Acres*		
W-3	0–1	10.0	54756	$8,213.40			
	1–2	11.7	71769	10,765.35			
	2–3	15.6	119602	17,940.30			
	3–4	18.0	161920	24,288.00			
	4–5	14.7	107517	16,127.55			
	5–6	15.9	123709	18,556.35			
	6–7	15.3	115495	17,324.25			
	7–8	15.4	116864	17,529.60			
	8–9	15.0	111467	16,720.05			
	9–10	10.8	62500	9,375.00			
	10–10.4	2.5	1607	241.05			
	10–10.4	5.9	4517	677.55	6451.9	$157,758.45	$24.45
W-1	0–1	17.4	152455	22,868.25			
	1–2	16.1	132861	19,929.15			
	2–3	16.0	131414	19,712.10			
	3–4	15.9	123709	18,556.35			
	4–5	16.7	141739	21,260.85			
	5–6	15.2	114126	17,118.90			
	6–7	16.6	140253	21,037.95			
	7–8	17.6	155584	23,337.60			
	8–9	19.2	181711	27,256.65			
	9–10	19.1	180029	27,004.35			
	10–10.1	2.6	284	42.60	4664.0	218,124.75	46.77
H-W-1	0–1	14.0	98560	14,784.00			
	1–2	15.6	119602	17,940.30			
	2–3	15.2	114126	17,118.90			
	3–4	14.6	106226	15,933.90			
	4–5	12.9	85262	12,789.30			
	5–6	16.0	131414	19,712.10			
	6–7	16.0	131414	19,712.10			
	7–7.9	12.4	71562	10,734.30	3088.3	128,724.90	41.68
Total for Washington sheet (1899)					14204.2	$504,608.10	$35.52

Preliminary Estimates of Levees—Average Heights, Yardage, and Cost—Continued.

Howth Sheet—Flood of 1908.

Designation of Levee Division	By Mile Sections				By Levee Divisions		
	Between mile-marks	Average height of levee	Amount of material in section	Cost of section at 15c per cubic yard	Total over-flowed area	Total cost at 15c per cubic yard	Cost of re-clamation per acre
		Feet	*Cubic yards*		*Acres*		
H-6 (Secondary)	4–1	4.2	11812	$1,771.80			
	1–2	3.7	9700	1,455.00			
	2–3	7.1	28043	4,206.45			
	3–4	7.6	13240	1,986.00	482.4	$9,419.25	$19.53
H-5	0–1	11.5	69696	10,454.40			
	1–2	8.2	35904	5,385.60			
	2–3	10.0	54756	8,213.40			
	3–4	9.9	53817	8,072.55			
	4–5	9.0	45760	6,864.00			
	5–6	6.7	25422	3,813.30			
	6–7	6.3	22880	3,432.00			
	7–8	4.6	13298	1,994.70			
	8–9	5.1	16153	2,422.95			
	9–9.3	5.0	5006	750.90	3992.6	51,403.80	12.87
H-4 (Secondary)	0–1	4.7	13554	2,033.10			
	1–2	5.3	17209	2,581.35			
	2–2.4	4.0	2957	443.55	527.4	5,058.00	9.59
H-3	0–1	6.0	21120	3,168.00			
	1–2	6.2	22293	3,343.95			
	2–3	6.4	23506	3,525.90			
	3–4	6.1	21707	3,256.05			
	4–5	6.6	24796	3,719.40			
	5–6	6.6	24796	3,719.40			
	6–7	5.5	18265	2,739.75			
	7–8	7.2	28708	4,306.20			
	8–9	7.5	30781	4,617.15			
	9–10	7.1	28043	4,206.45			
	10–11	7.9	33675	5,051.25			
	11–12	8.9	41419	6,212.85			
	12–13	7.5	30781	4,617.15			
	13–14	9.0	45760	6,864.00			
	14–15	6.1	21707	3,256.05			
	15–16	5.2	16661	2,499.15			
	16–17	5.9	20533	3,079.95			
	17–17.7	3.0	1901	285.15			
	17–17.7	3.3	2196	329.40	7739.8	$68,797.20	$8.89
H-2 (Secondary)	0–1.2	8.0	39925	5,988.75	229.5	5,988.75	26.09
H-1	0–1	5.9	9856	1,478.40			
	1–2	5.6	18812	2,821.80			
	2–3	6.0	21120	3,168.00			
	3–4	7.2	28708	4,306.20			
	4–5	6.1	21707	3,256.05			
	5–5.5	8.0	17209	2,581.35	2455.5	17,611.80	7.17
Total for Howth sheet (1908)					15427.2	$158,278.80	$10.26

Preliminary Estimates of Levees—Average Heights, Yardage, and Cost—Continued.
Howth Sheet—Flood of 1899.

Designation of Levee Division	By Mile Sections				By Levee Divisions		
	Between mile-marks	Average height of levee	Amount of material in section	Cost of section at 15c per cubic yard	Total over-flowed area	Total cost at 15c per cubic yard	Cost of re-clamation per acre
H-5	0–1	16.9	144751	$21,712.65			
	1–2	13.4	91207	13,681.05			
	2–3	15.0	111467	16,720.05			
	3–4	15.0	111467	16,720.05			
	4–5	14.1	99812	14,971.80			
	5–6	11.8	72864	10,929.60			
	6–7	11.9	73959	11,093.85			
	7–8	11.0	64533	9,679.95			
	8–9	11.9	73959	11,093.85			
	9–9.3	11.8	24774	3,716.10	3992.6	$130,318.95	$32.64
H-3	0–1	11.4	67623	10,143.45			
	1–2	11.7	71769	10,765.35			
	2–3	11.8	72864	10,929.60			
	3–4	11.5	69696	10,454.40			
	4–5	12.0	75094	11,264.10			
	5–6	12.0	75094	11,264.10			
	6–7	10.8	62500	9,375.00			
	7–8	12.4	79513	11,926.95			
	8–9	12.9	85262	12,789.30			
	9–10	12.8	84089	12,613.35			
	10–11	13.8	96057	14,408.55			
	11–12	15.1	112797	16,919.55			
	12–13	14.0	98560	14,784.00			
	13–14	16.0	131414	19,712.10			
	14–15	13.4	91207	13,681.05			
	15–16	12.2	77284	11,592.60			
	16–17	12.9	85262	12,789.30			
	17–17.7	8.4	12352	1,852.80			
	17–17.7	10.1	18617	2,792.55	7739.8	220,058.10	28.43
H-1 (Incomplete)	0–1	9.4	49280	7,392.00			
	1–2	12.2	77284	11,592.60			
	2–3	12.5	80647	12,097.05			
	3–4	13.8	96057	14,408.55			
	4–5	12.7	82955	12,443.25			
	5–5.5	14.5	52467	7,870.05	2455.5	65,803.50	26.80
Total for Howth sheet (1899)					14187.9	$416,180.55	$29.33

Note—The quantities in the column "Average height of levee" should be obtained by averaging the squares of the heights. The average of the heights may be used, however, when the individual heights do not vary more than one foot either way from the average, and is amply accurate for preliminary estimates, such as the above.

RESULTS OF PRIMARY TRAVERSE AND LEVELING ALONG EAST FORK OF TRINITY RIVER, BRAZOS RIVER AND LITTLE RIVER.

ROCKWALL SHEET—Collin, Rockwall and Dallas Counties.

(By the U. S. Geological Survey in Co-operation with the State Levee and Drainage Board. See U. S. Geological Survey Bulletins Nos. 496 and 468 for descriptions of benchmarks along these rivers not given herein.)

Elevation above Sea Level	Description of Benchmark.	Latitude	Longitude
Feet		° ′ ″	° ′ ″
412.41 T. B. M.	Rockwall, 1.5 miles west by 1.9 miles south of, 13 feet from primary traverse station 343, corner of brush land; copper nail in root of tree.	32–54–20.5	96–28–44.3
414.24 T. B. M.	Rockwall, 1.5 miles west by 0.3 mile south of, primary traverse station 350 plus 142.5; copper nail in bois d'arc stump.	32–55–22.0	96–28–50.6
415.809 B. M.	Rockwall, 1.5 miles west of, 40 feet south of road, about 40 feet east of slough bridge, in edge of timber land; iron post stamped "Prim. Trav. Sta. No. 13, 1909, 416."	32–55–35.2	96–29–04.9
413.75 T. B. M.	Rockwall, 1.5 miles west by 0.8 mile north of, 150 feet south of Rockwall-Dallas road, at primary traverse station 361; copper nail in root of elm tree.	32–55–29.1	96–29–51.6
418.82 T. B. M.	Rockwall, 1.5 miles west by 1.6 miles north of, 26.6 feet west of primary traverse station 365; copper nail in root of bois d'arc tree.	32–56–08.5	96–29–54.4
427.87 T. B. M.	Rockwall, 1.5 miles west by about 3.5 miles north of, in edge of timber just outside of field and about 40 feet from west bank of river; copper nail in leaning mulberry tree, 8 inches in diameter.	32–58–05.3	96–29–58.2
427.57 T. B. M.	Rockwall, 5 miles north by 1.5 miles west of, 35 feet northeast of primary traverse station 384, in edge of timber; copper nail in hackberry tree.	32–58–52.6	96–29–51.6
433.046 B. M.	Rockwall, about 5.5 miles west of, northeast corner of N. F. Evan's field, south side of road; iron post stamped "Prim. Trav. Sta. No. 15, 1909, 433."	32–59–12.4	96–29–50.1
431.24 T. B. M.	Rockwall, 6 miles north by 1.5 miles west of, 39 feet west of primary traverse station 389, on line between two fields; copper nail in root of water elm tree.	....	....
432.71 T. B. M.	Rockwall, 6.4 miles north by 1.5 miles west of, 16.4 feet north of primary traverse station 391, in fence line; copper nail in elm tree.	32–59–33.4	96–29–07.1
435.82 T. B. M.	Rockwall, 7 miles north by 1.5 miles west of, primary traverse station 393 plus 119.3, on river bank; copper nail in root of water elm tree.	32–59–50.2	96–29–15.5
417.200 B. M.	Rockwall, 2.5 miles west of, in top of north end of east abutment of M. K. & T. Ry. bridge over Trinity River; aluminum tablet stamped "Prim. Trav. Sta. No. 4, 1909."	32–53–59.8	96–29–04.6
407.84 T. B. M.	Barnes Bridge, 4.5 miles north of, east of road, 20 feet west of river bank; copper nail in root of burr-oak tree.	32–53–25.4	96–29–24.0
405.05 T. B. M.	Barnes Bridge, 3.9 miles north of, 51.5 feet from primary traverse station 112; nail in root of leaning burr-oak.	32–53–02.9	96–29–38.9

.... T. B. M.	Southeast corner of bridge over East Fork of Trinity River.	32–55–27.0	96–30–19.6
421.69 T. B. M.	Rockwall, 1.5 miles west by 2.1 miles north of, 4.5 feet southwest of primary station 368, on bank of river; copper nail in root of 20-inch leaning oak tree.	32–56–30.1	96–30–08.3
422.10 T. B. M.	Rockwall, 1.5 miles west by 2.5 miles north of, primary traverse station 369 plus 519.7, 100 feet east of river; copper nail in root of spotted oak.	32–56–51.2	96–30–18.3
422.362 B. M.	Rockwall, 2.8 miles north by 1.5 miles west of, about 2 miles north of Dallas-Rockwall road, 400 feet east of East Fork of Trinity River, in west edge of timber; iron post stamped "Prim. Trav. Sta. No. 14, 1909, 422."	32–57–09.3	96–30–24.0
424.14 T. B. M.	Rockwall, 3.1 miles north by 1.5 miles west of, 63.2 feet east of primary traverse station 375; copper nail in root of 16-inch hackberry tree.	32–57–22.7	96–30–20.2
427.56 T. B. M.	Rockwall, 4.8 miles north by 1.5 miles west of, 100 feet west of slough; copper nail in top of bois d'arc stump, at primary traverse station 382.	32–58–37.0	96–30–01.1
423.303 B. M.	Rowlett, 1.5 miles east of, 30 feet south of west end of west M. K. & T. bridge over Muddy Creek, in corner of right of way fence; iron post stamped "423 1909."	....	....
419.46 T. B. M.	Rowlett, 2 miles southeast of, 0.6 miles south of M. K. & T. R. R. along Muddy Creek, northeast corner of wooden bridge; copper nail.	....	....
417.71 T. B. M.	Rowlett, 2.2 miles southeast of, 0.8 mile south of M. K. & T. R. R., southwest corner of iron bridge over Muddy Creek; copper nail.	....	....

BARNES BRIDGE SHEET—Dallas, Rockwall and Kaufman Counties.

401.99 T. B. M.	Barnes Bridge, 2 miles north of, at primary traverse station 135; copper nail in top of stump 2 feet high near edge of field.	32–51–41.6	96–30–15.7
399.583 T. B. M.	Barnes Bridge, 1.5 miles north of, primary traverse station 140; copper nail in notch in base of mulberry tree.	32–51–15.7	96–30–14.0
398.870 B. M.	Barnes Bridge, 1 mile north of; iron post stamped "Prim. Trav. Sta. No. 6, 1909, 399."	32–50–47.9	96–30–14.4
396.99 T. B. M.	Barnes Bridge, on east bank of river above; at bend of river, copper nail in red elm.	32–50–21.5	96–30–29.0
408.257 B. M.	Barnes Bridge, 130 feet east of, in field south of road; iron post stamped "Prim. Trav. Sta. No. 7, 1909, 408.":	32–50–12.0	96–30–31.6
397.27 T. B. M.	Barnes Bridge, 0.7 mile south of, primary traverse station 168; copper nail in 6-inch stump 15 inches high.	32–49–44.4	96–30–53.1
395.92 T. B. M.	Barnes Bridge, 1 mile south of, primary traverse station 159; nail in root of old dois d'arc stump in open ground.	32–49–32.3	96–30–58.3
394.00 T. B. M.	Barnes Bridge, 1.4 miles south of, primary traverse station 163; copper in nail small stump 15 inches high.	32–49–12.6	96–31–05.3

RESULTS OF PRIMARY TRAVERSE AND LEVELING—Continued.

BARNES BRIDGE SHEET—Dallas, Rockwall and Kaufman Counties—Continued.

Elevation above Sea Level	Description of Benchmark	Latitude	Longitude
Feet		° ′ ″	° ′ ″
391.83 T. B. M.	Barnes Bridge, 1.9 miles south of, primary traverse station 166; copper nail in top of 8-inch stump.	32–48–42.2	96–31–07.8
388.85 T. B. M.	Barnes Bridge, 2.4 miles south of, primary traverse station 173, 250 feet south of fence; nail in root of leaning ash tree.	32–48–19.7	96–30–54.0
391.52 T. B. M.	Barnes Bridge, 2.9 miles south of primary traverse station 177; copper nail top of 8-inch stump.	32–47–54.9	96–30–56.0
389.446 B. M.	Barnes Bridge, 3.4 miles south of, about 0.8 mile north of Dallas-Forney road, 320 feet south of corner of wire fence at east and west lane, 18 inches west of wire fence on land of Jeff Caldwell; iron post stamped "Prim. Trav. Sta. No. 8, 1909, No. 17."	32–47–30.9	96–30–59.3
388.02 T. B. M.	Barnes Bridge, 4.2 miles south of, primary station (traverse) 184 plus 898; copper nail in root of tree.	32–46–53.0	96–30–51.3
382.41 T. B. M.	Barnes Bridge, 5 miles south of, primary traverse station 191 plus; copper nail in hackberry tree.	32–46–29.7	96–30–19.5
381.02 T. B. M.	Barnes Bridge, 6.9 miles south of, primary traverse station 204, 75 feet southwest of levee; copper nail in leaning elm tree at corner of field.	32–45–28.4	96–30–04.6
383.817 B. M.	Mesquite, 5.4 miles east of, T. & P. R. R. crossing of East Fork of Trinity River, 48 feet east of northeast corner of wagon bridge, about 15 feet north of center of wagon road, 162 feet south of center of railway water tank; iron post stamped "Prim. Trav. Sta. No. 10, 1909, N. 22."	32–45–02.3	96–30–31.0
383.581 B. M.	Barnes Bridge, 5.8 miles south of, 800 feet south of bridge over East Fork of Trinity River, at turn of road, near slough, 40 feet south of road corner, on Dallas-Forney road; iron post stamped "Prim. Trav. Sta. No. 9, 1909, No. 29, 1909."	32–46–06.0	96–29–55.5
....	On dead bois d'arc stump.	32–46–05.7	96–29–43.3
403.602 B. M.	Barnes Bridge, 3.3 miles north of, 2.5 miles south of M. K. & T. Ry. bridge, 300 feet east of river; iron post stamped "Prim. Trav. Sta. No. 5, 403, 1909."	32–52–24.1	96–29–45.2
402.78 T. B. M.	Barnes Bridge, 2.7 miles north of, 29.5 feet from primary traverse station 129; copper nail.	32–52–01.3	96–29–59.9
412.63 T. B. M.	Rowlett, 3.3 miles southeast of, 0.5 mile below junction of Muddy Creek and Rowlett Creek, 0.2 mile north of bridge over Rowlett Creek, 300 feet northeast of levee; copper nail in east side of dead bois d'arc tree.	....	....
412.23 T. B. M.	Rowlett, 3.4 miles southeast of, 600 feet northwest of bridge over Rowlett Creek; copper nail in northwest corner of small bridge.	....	....

421.60 T. B. M.	Rowlett, 2.2 miles south of, 20 feet south of southeast corner of bridge over Rowlett Creek; iron post stamped "1909."	....	....
428.592 B. M.	Newhope, 2.6 miles northeast of, 30 feet south of west end of bridge over Duck Creek; iron post stamped "1909."	....	....
407.028 B. M.	Barnes Bridge, 3 miles northwest of, iron bridge over Rowlett Creek, 10 feet north of east end of bridge; iron post stamped "407, 1909."	....	....
401.61 T. B. M.	Barnes Bridge, 1.6 miles west of, by 1 mile north, north end of culvert at T road west; copper nail.	....	....
397.23 T. B. M.	Barnes Bridge, 1.6 miles west of, southeast corner of bridge at T road north; copper nail.	....	....
	BUCKHOLTS SHEET—Milam County.		
361.67 T. B. M.	Haw Creek, 2.4 miles northwest of, between Rockdale-Cameron road and Cummings Bridge road, on north bank of water course, 8 feet south of wire fence, copper nail in root of elm tree; painted "362, No. 62."	30–48–49.4	97–07–51.9
361.135 B. M.	Haw Creek, 2.8 miles northwest of, about 0.2 mile east of Cummings Bridge road, 200 feet south of a series of low hills, on east bank of slough, in open cultivated field, 8 feet east of wire fence; iron post stamped "Prim. Trav. Sta. No. 17, 362."	30–49–05.4	97–08–11.9
364.30 T. B. M.	Haw Creek, 3.3 miles northwest of, about 800 feet north of Cummings Bridge road, in center of large open cultivated field, copper nail in root of lone elm tree; painted "365, No. 63."	30–49–16.7	97–08–40.2
359.666 T. B. M.	Haw Creek, 3.7 miles northwest of, about 3000 feet from Cummings Bridge road, in timbered pasture on west bank of slough and 75 feet east of wire fence, in open cultivated field, copper nail in root of leaning elm tree; painted "360, No. 64."	30–49–28.2	97–09–03.8
365.933 T. B. M.	Haw Creek, 4.1 miles northwest of, at fenceline between pasture and open field, copper nail in root of hackberry tree; painted "366, No. 65."	30–49–46.0	97–09–14.4
368.662 T. B. M.	Haw Creek, 4.8 miles northwest of, in narrow neck of woods extending out into an open cultivated field, copper nail in root of elm tree; painted "369, No. 66."	30–50–12.3	97–09–42.4
372.038 B. M.	Haw Creek, 5.2 miles northwest of, on land of J. M. Corley, about 0.5 mile northwest of Corley's house, at end of narrow neck of woods, large cultivated field to north, 250 feet east of slough; iron post stamped "Prim. Trav. Sta. No. 18, 372."	30–50–12.1	97–09–56.9
377.650 T. B. M.	Buckholts, about 6 miles south of station, in large open cultivated field, about 1000 feet west of fringe of low hills, 0.2 mile southwest of house on hill, 40 feet northeast of tree blazed and marked, copper nail in stump of small double willow tree; painted "378, No. 67."	30–50–25.9	97–10–24.6
378.252 T. B. M.	Bryant Bridge, 0.9 mile southeast of, in timbered pasture, about 500 feet south of low fringe of hills, on north bank of slough 10 feet south of a wire fence, copper nail in root of willow tree; painted "379, No. 68."	30–50–40.4	97–10–53.5
430.817 B. M.	Bryant Bridge, 600 feet north of, 85 feet west of road to station, at east fence line, at edge of wooded land, 0.1 mile northeast of river; iron post stamped "Prim. Trav. Sta. No. 19, 431."	30–51–00.0	97–11–40.9
424.79 T. B. M.	Bryant Bridge, about 2500 feet west of crossroad to, on property of Mr. Guschback, about 300 feet east of house, in timbered pasture, 15 feet east of wire fence between pastures, copper nail in root of elm tree; painted "425, No. 69."	30–51–16.0	97–12–04.2

RESULTS OF PRIMARY TRAVERSE AND LEVELING—Continued.

BUCKHOLTS SHEET—Milam County—Continued.

Elevation above Sea Level	Description of Benchmark	Latitude	Longitude
Feet		° ′ ″	° ′ ″
388.14 T. B. M.	Bryant Bridge, 1.2 miles northwest of, at fence line between pasture and open cultivated field, about 50 feet east of joining of pasture with another field, copper nail in root of elm tree; painted "389, No. 70."	30–51–28.8	97–12–39.0
389.31 T. B. M.	Bryant Bridge, 1.8 miles northwest of, in open cultivated field in cluster of four large oak trees, copper nail in root of large leaning oak tree; painted "390, No. 71."	30–51–35.7	97–13–16.7
391.861 B. M.	Bryant Bridge, 2.6 miles northwest of, at fence line between two timbered pastures, 20 feet north of private pasture road, 25 feet east of cleared fields of Frank A. Cox, near tree blazed and marked; iron post stamped "392, Prim. Trav. Sta. No. 20.'	30–51–55.9	97–13–49.2
396.14 T. B. M.	Bryant Bridge, 3.2 miles northwest of, on property of Mr. Clarey, next to land of Mrs. Nichols, 12 feet south of narrow lane, 90 feet southeast of well, 500 feet east of house on hill; lane runs between open cultivated field and pasture and is used mostly as cattle lane to river; copper nail in root of large elm tree; painted "397, No. 72."	30–52–10.9	97–14–25.2
....	Northeast pillar of bridge across river.	30–52–06.4	97–14–50.2
401.181 T. B. M.	Bryant Bridge, 3.9 miles northwest of, on left bank of Little River, on west margin of Rogers-Davilla public road, 5 to 6 miles from Rogers, 0.1 mile north of road bridge across river, very deep, dry watercourse about 200 feet to the north, woods to west, open field to east, copper nail in root of leaning ash tree; painted "402, No. 73."	30–52–12.9	97–14–53.2

MILLICAN SHEET—Brazos, Washington and Grimes Counties.

Elevation above Sea Level	Description of Benchmark	Latitude	Longitude
187.87 T. B. M.	Navasota Bridge, 1.5 miles north of, 100 feet east of road, spike in root of pecan tree; painted "185, 5".	30–22–53.3	96–08–55.6
189.640 B. M.	Navasota River Bridge, 1.8 miles north of, 20 feet east end of bridge over slough, iron post stamped "187, 29, Prim. Trav. Sta. 48A."	30–22–56.7	96–09–15.2
188.82 T. B. M.	Navasota River Bridge, 2.2 miles north of, south margin of road, spike in root of elm tree; painted "186, 6."	30–23–06.8	96–09–40.8
193.047 B. M.	Brazos River, Hidalgo Falls, 400 feet east of Lock No. 1, 10 feet northeast of corner of office building; iron post stamped "190, 30, Prim. Trav. Sta. 49A."	30–23–06.8	96–10–20.6
195.78 T. B. M.	Brazos River, Lock No. 1, 0.5 mile north of, 30 feet east of road, spike in root of pecan tree; painted "193, 7."	30–23–29.5	96–10–24.0
192.64 T. B. M.	Brazos River, Lock No. 1, 0.9 mile north of east margin of road, spike in root of tree; painted "190, 8."	30–23–49.0	96–10–21.1
193.22 T. B. M.	Harrington Switch, 100 feet south of railroad, 100 feet west of highway, spike in root of tree; painted "191, 9."	30–24–08.6	96–10–12.9

192.524 B. M.	Harrington Switch, 0.5 mile west of, 20 feet north of railroad milepost 22, at fence line; iron post stamped "189, 31, Prim. Trav. Sta. 50A."	30–24–08.7	96–10–49.6
192.65 T. B. M.	Harrington Switch, 1.1 miles west of, 340 feet west of levees, 25 feet north of track, in telephone pole; painted "190, 10."	30–24–07.1	96–11–22.2
193.75 T. B. M.	Harrington Switch, 1.6 miles west of, 150 feet west of milepost 21, 25 feet north of track, in telephone pole; painted "191, 11."	30–24–06.0	96–11–51.3
194.02 T. B. M.	Harrington Switch, 2.2 miles west of, 25 feet north of track, in telephone pole; painted "191, 12."	30–24–04.6	96–12–23.8
198.236 B. M.	Harrington Switch, 2.5 miles west of, at milepost 20, north side of track; iron post stamped "195, 32, Prim. Trav. Sta. 51A."	30–24–03.6	96–12–51.3
200.84 T. B. M.	Harrington Switch, 3 miles west of, railroad bridge 2042, north side, east end; top of most easterly bolt in guard rail; painted "198, 13."	30–24–01.8	96–13–23.4
194.12 T. B. M.	Allen Farm, 0.6 mile east of, 29 feet north of track, in telephone pole, spike; painted "191, 14."	30–24–01.0	96–13–49.5
201.85 T. B. M.	Allen Farm, 70 feet west of station, 28 feet north of track, in telephone pole; painted "199, 15."	30–23–59.4	96–14–27.7
204.227 B. M.	Allen Farm, 2000 feet west of, 45 feet west of milepost 18, at fence line; iron post stamped "201, 33, Prim. Trav. Sta. 52A."	30–23–58.5	96–14–52.2

WASHINGTON SHEET—Washington, Brazos and Grimes Counties.

204.00 T. B. M.	Graball-Washington road, 600 feet from, west side of road, spike in root of post oak tree; painted "200, 47."	30–16–57.6	96–07–33.6
229.01 T. B. M.	Grabah, 1.6 miles north of, at three corners, east margin of road, spike in root of post oak, painted "225."	30–17–18.1	96–08–06.4
228.183 B. M.	Old Washington, 150 feet southwest of the southwest corner of old brick building, 356 feet southwest of monument, 75 feet south of signboard, near old fence post; iron post stamped "225, 26, Prim. Trav. Sta. 35."	30–19–30.2	96–09–26.5
182.39 T. B. M.	Old Washington, 0.8 mile north of, on Navasota-Washington road, at northeast corner of wooden bridge on Jordan Creek, in plank, copper nail; marked "U. S. B. M., 179."	30–20–03.8	96–09–46.6
196.324 B. M.	Old Washington, on road bridge over Brazos River; tablet stamped "193, Prim. Trav. Sta. 36."	30–20–15.7	96–09–36.4
190.85 T. B. M.	Washington, bridge over Brazos River, 0.5 mile northeast of, spike in root of pecan tree, painted "188, 1."	30–20–46.0	96–09–17.6
183.45 T. B. M.	Washington, bridge over Brazos River, 1.1 miles northeast of, north margin of road, spike in root of hackberry tree; painted "180, 2."	30–21–05.2	96–09–05.3
.... T. B. M.	Old Washington, 2.4 miles northeast of, 15 feet west of road, in root of hackberry tree; painted "184, 3"; copper nail.	30–21–15.4	96–08–42.3

RESULTS OF PRIMARY TRAVERSE AND LEVELING—Continued.

WASHINGTON SHEET—Washington, Brazos, and Grimes Counties—Continued.

Elevation above Sea Level	Description of Benchmark	Latitude	Longitude
Feet		° ′ ″	° ′ ″
188.174 B. M.	Navasota River Bridge, 200 feet west of, at road leading up Brazos River, corner of fence; iron post stamped "185, 28, Prim. Trav. Sta. 37."	30–21–50.4	96–08–33.2
189.076 B. M.	Wilson's gin, 0.4 mile northwest of, 500 feet north of road to bottom, 6 feet east of north-south fence between cotton-fields at edge of bottom; iron post stamped "189, Prim. Trav. Sta. 38A." (PBM No. 47A.)	30–21–02.8	96–07–48.1
.... T. B. M.	Wilson's gin, 400 feet southeast of, 20 feet northeast of road, in root of red-oak tree, copper; painted "193.2 1-A."	30–20–44.8	96–07–35.8
.... T. B. M.	Navasota River Bridge, 0.6 mile north of, on west post of gateway of wire fence, rail at bottom; marked "182 4."	30–22–11.9	96–08–51.9
183.92 T. B. M.	Courtney, 0.9 mile south of, at bridge "62 C" on H. & T. C. Ry., top of northerly bolt head in western longitudinal brace; marked "182.6."	....	....
185.121 B. M.	Courtney, on Houston & Texas Central Ry., at foot of principal street, 75 feet east of south end of station, at corner; iron post stamped "185 Prim. Trav. Sta. 44A." (As reset.)	30–15–54.8	96–04–05.7
184.49 T. B. M.	Courtney, 1.4 miles north of, just south of road crossing, in easterly wooden girder for cattle-guard, southernmost bolt head; marked "183.3."	30–17–04.5	96–04–05.6
181.723 B. M.	Courtney, 2.5 miles north of, 50 feet west of Houston & Texas Central R. R. track, at road crossing, 0.2 mile north of negro cabin; iron post stamped "181 Prim. Trav. Sta. 45A."	30–17–51.9	96–04–05.4
188.99 T. B. M.	Courtney, 2.9 miles north of, 30 feet south of road crossing, on south end, east side, of trestle, bolt; painted "188.097 10-A."	30–18–29.1	96–04–07.2
189 03 T. B. M.	Courtney, 4.6 miles north of, on west end of southernmost transverse girder in bridge of H. & T. C. R. R. over Walkers Creek; chiseled cross mark "188.2."	30–19–44.9	96–04–22.4
198.112 B. M.	Walkers Creek, 0.9 mile northwest of H. & T. C. R. R. bridge over, on Wilson's plantation, about 0.5 mile west of railway, 15 feet west of 24-inch oak which stands alone in small tongue of highland; iron post stamped "197 Prim. Trav. Sta. 46A."	30–20–22.5	96–05–02.1
189.92 T. B. M.	Barron's plantation, 75 feet south of house, distinguishable by a white stone chimney to south, copper nail in root of 36-inch oak; marked "189.4."	30–20–30.1	96–06–00.3
188.81 T. B. M.	Barron's house, 900 feet north of, on east side of road to gin, opposite newly built negro cabin, copper nail in root of 12-inch tree; painted "188.4."	30–20–46.4	96–06–44.9
218.69 T. B. M.	Graball, about 2 miles southeast of, 0.1 mile east of T-lane southeast, copper nail in root of pecan tree; painted "216."	30–15–27.2	96–06–52.4

176.50 T. B. M.	Flat Prairie Church, 0.5 mile south of, east of road, copper nail in root of elm tree; painted "174."	30–15–53.2	96–06–51.9
187.574 B. M.	Flat Prairie Church, opposite, 6 feet east of gate, north side of road; iron post stamped "185 24 Prim. Trav. Sta. 33."	30–16–10.4	96–07–11.0

HOWTH SHEET—Washington, Grimes and Waller Counties.

164.923 B. M.	New Years Creek, county bridge over, east side, top of north abutment, aluminum tablet stamped "165 18 Prim. Trav. Sta. 27."	30–08–04.8	96–11–30.8
163.02 T. B. M.	McGregor Farm, south side of road, spike in root of pecan tree; painted "163."	30–08–50.5	96–10–55.3
157.82 T. B. M.	Grand Point, opposite, east side of road, spike in root of elm tree; painted "168."	30–09–19.6	96–10–15.9
163.742 B. M.	Riverside plantation, 0.5 mile west of, 200 feet south of gate to lane, opposite old house, at west margin of road; iron post stamped "164 19 Prim. Trav. Sta. 28."	30–09–51.3	96–10–16.0
167.74 T. B. M.	Henry Hughes' plantation, at edge of river, spike in root of Spanish oak tree; painted "168."	30–10–07.7	96–10–10.6
167.57 T. B. M.	R. R. Felder's farm, west side of road, spike in root of tree; painted "168."	30–10–48.6	96–10–38.7
167.787 B. M.	J. F. Buchanan's land, at southwest line, 30 feet north of old river levee, at road to negro houses; iron post stamped "168 20 Prim. Trav. Sta. 29."	30–11–15.3	96–10–35.0
166.68 T. B. M.	J. F. Buchanan's land, 0.25 miles west of house, on west side of road, spike in root of tree; painted "167."	30–11–37.6	96–09–58.1
167.09 T. B. M.	J. F. Buchanan's land, north side of road, spike in root of tree; painted "167."	30–12–14.0	96–10–13.0
171.062 B. M.	Buchanan's house, 130 feet north of, on Gidding's and Buchanan's land, north end of dam across Jackson Creek, at end of wire fence; iron post stamped "171 21 Prim. Trav. Sta. 30."	30–12–22.7	96–10–07.5
192.43 T. B. M.	Gidding's and Buchanan's land, near house occupied by Jim Franklin, spike in root of oak; painted "192."	30–13–00.8	96–10–04.9
191.51 T. B. M.	Lott's place, east side of road, spike in root of Spanish oak; painted "192."	30–13–26.7	96–09–28.1
196.274 B. M.	Jackson Creek Dam, 1.5 miles north of Jim Lott's land, near house occupied by Martin Avery (colored), at wire gate; iron post stamped "196 22 Prim. Trav. Sta. 31."	30–13–42 4	96–09–02.2
164.172 B. M.	Stone's gin, 1500 feet southeast of, on Stone plantation, 6 feet north of road from house, on hill to east, 5 feet from gin house, 15 feet southeast of 30-inch pecan tree which stands alone in cotton field; iron post stamped "162 Prim. Trav. Sta. 38A."	30–08–24.6	96–09–06.4
177.657 B. M.	John Torrey's house, 200 feet northeast of, 150 feet south of stable, 100 feet southeast of 8-inch dead pecan tree, about 1.5 miles southwest of Wood's ginhouse; iron post stamped "175 Prim. Trav. Sta. 39A."	30–09–53.6	96–08–54.0

RESULTS OF PRIMARY TRAVERSE AND LEVELING—Continued.

HOWTH SHEET—Washington, Grimes and Waller Counties—Continued.

Elevation above Sea Level	Description of Benchmark	Latitude	Longitude
Feet		° ′ ″	° ′ ″
169.37 T. B. M.	John Torrey's house, 0.8 mile north of, 100 feet northeast or mouth of big ditch dug on cut-off, 5 feet east of river bank at north edge of timber; nail in root of 12-inch cottonwood tree; marked "167.1."	30–10–23.2	96–09–15.3
180.633 B. M.	John Torrey's house, 1.1 miles northeast of, 75 feet south of field road through Loch Buchanan's bottom, 50 feet west of edge of cotton and corn fields, 15 feet west of 16-inch oak, which stands 500 feet east of thicket and is distinguishable by being the only oak in the field with leaves on top; iron post stamped "178 Prim. Trav. Sta. 40A."	30–10–39.5	96–09–04.6
203.95 T. B. M.	Wood's gin, about 0.6 mile north of, southwest corner of crossroads, at wire fence, copper nail in root of 24-inch oak; marked "200.7."	30–10–36.1	96–07–36.0
190.13 T. B. M.	Wood's gin, about 1 mile north of, on west side of road, nail in root of elm tree; painted "186.9."	30–11–10.4	96–07–10.2
171.659 B. M.	Wood's gin, 2.3 miles northeast of, at south edge of Clark's bottom, 75 feet east along road to cast at foot of lane, 0.2 mile north of John Marshall's house; iron post stamped "168, Prim. Trav. Sta. 41A.".	30–11–35.0	96–07–10.0
169.23 T. B. M.	Charles Thornton's cotton field, southwest corner of, about 0.8 mile southwest of house, 200 feet from west timber line, 1000 feet from south timber line; nail in root of 24-inch pecan tree, marked "166.2."	30–12–02.1	96–07–01.4
173.36 T. B. M.	Charles Thornton's house, in foot of brick pier under porch at southeast corner; cross cut on brick, marked "171.3."	30–12–28.8	96–06–39.5
175.230 B. M.	Charles Thornton's house, 0.8 mile northeast of, 400 feet south of cabin, 10 feet south of large pecan trees (2) which stand alone in field about 75 feet east of road; iron post stamped "173 Prim. Trav. Sta. 42A."	30–12–41.8	96–05–57.4
179.90 T. B. M.	Charles Thornton's house, 1.6 miles northeast of, 150 feet back of gate at fence corner, at corner of old field, cotton field and timber, on east side of road to railroad; nail in root of 12-inch hackberry tree; marked "173.9."	30–12–57.4	96–05–09.3
215.74 T. B. M.	Courtney, 3.5 miles south of, 20 feet east of milepost 59, on south end and west side of small wooden culvert; bolt painted red; painted "B. M. 8-A."	30–12–57.5	96–04–23.5
194.072 B. M.	Courtney, 2.5 miles south of, 100 feet morth of milepost 60, 300 feet north of Grimes-Waller county line post, at northwest corner of road crossing with H. & T. C. R. R.; iron post stamped "192 Prim. Trav. Sta. 43A."	30–13–51.2	96–04–16.4
182.21 T. B. M.	Courtney, 1.7 miles south of, bridge "61A" on H. & T. C. R. R. west wing wall of south abutment, in stone 30 inches from south end, 8 inches from west edge; chiseled cross in circle; marked "180.5."	30–14–27.9	96–04–10.6

RESULTS OF PRIMARY TRAVERSE AND LEVELING.

From Dallas, along Trinity River, via Eagle Ford, Grand Prairie and Tarrant to Ft. Worth; and northeast along T. & P. Ry. to Boons Triangulation Station, near Keller.

(Independent Work of the State Levee and Drainage Board.)

Elevation above Sea Level	Description of Benchmark	Latitude	Longitude	Distance to Point Indicated
Feet		° ′ ″	° ′ ″	*Feet*
U. S. G. S. B. M. "Prim. Trav. Sta. No. 12."	Dallas, about 1100 ft. west of fair ground entrance, in masonry abutment at east end of Texas & Pacific Ry. bridge No. 213-A, about 530 ft. east of crossing of Texas & Pacific Ry. and Gulf, Colorado & Santa Fe. Ry., in top course of masonry between railway tracks, 8 inches below top of rail; aluminum tablet stamped "Prim. Trav. Sta. No. 12, 1909, Texas." (See U. S. Geol. Survey Bul. 496, page 309.)	32–47–03.2	96–46–04.3	....
R. R. Crossing	Dallas, intersection of main tracks of Texas & Pacific Ry. and Gulf, Colorado & Santa Fe Ry.	32–47–04.9	96–46–10.6	530 to U. S. G. S. B. M. 12
414.832 Top of rail	Crossing of G. C. & S. F. R. R. and M. K. & T. R. R. Dallas.	32–45–34.6	96–47–14.7	10654 to T. & P. and Santa Fe crossing
412.636 Top of rail	Crossing of Interurban and M. K. & T. R. R. Dallas.	....	....	....
428.681 B. M. 1	Dallas, 2.3 miles southeast of, 110 ft. southeast of Santa Fe bridge, No. 6110, across Trinity River, 49 ft. west of Santa Fe Ry., north side of Hutchings road, 3 ft. inside fence corner, in Mr. Warren's pasture; iron post stamped "No. 1-428.7."	32–44–54.2	96–47–50.9	5102 to G. C. & S. F. and M. K. & T. R. R. crossing
400.525 T. B. M. 7	Dallas, 2 miles southeast of, about 500 ft. north of high ridge, spike in root of 10-inch pecan in fence line; painted "T. B. M. 7-400.5."	32–45–06.1	96–47–58.4	1363 to B. M. 1
401.107 T. B. M. 8	Dallas, 1.8 miles southeast of, spike in root of leaning 24-inch pecan farthest south of several scattering trees; painted "T. B. M. 8-401.1."	32–45–15.0	96–48–06.2	1120 to T. B. M. 7
402.813 T. B. M. 9	Dallas, 0.7 mile east of southeast end of Oak Cliff Viaduct, spike in root of lone 22-inch elm in field; painted "T. B. M. 9-402.8."	32–45–36.1	96–48–30.2	2960 to T. B. M. 8
401.352 T. B. M. 10	Dallas, 300 feet west of south end of viaduct, spike in south corner of floor of small wagon bridge; painted "T. B. M. 10-410.4."	32–45–51.5	96–48–50.6	2332 to T. B. M. 9
397.393 B. M. 2	Dallas, 1.5 miles southwest of courthouse, west side of road, 0.4 mile west of viaduct, 173 ft. north of small wagon bridge at angle in road, 1 ft. west of fence; iron post stamped "No. 2-397.4."	32–46–11.0	96–48–53.3	1991 to T. B. M. 10
426.744 T. B. M.	Dallas, crossing of Texas & Pacific Ry. and C. R. I. & P. Ry. Elevation, top of rail.	....	....	....

RESULTS OF PRIMARY TRAVERSE AND LEVELING—Continued.

From Dallas, along Trinity River, via Eagle Ford, Grand Prairie and Tarrant to Fort Worth; and Northeast along T. & P. Ry. to Boons Triangulation Station, near Keller—Continued.

Elevation above Sea Level	Description of Benchmark	Latitude	Longitude	Distance to Point Indicated
Feet		° ′ ″	° ′ ″	*Feet*
424.797 T. B. M. 11	Dallas, 900 ft. north of Commerce St. bridge, on C. R. I. & P. Ry., spike in east end of tie; rail painted "T. B. M. 11-424.8."	32–46–50.5	96–48–35.1	4279 to B. M. 2
414.012 T. B. M. 12	Dallas, 0.7 mile north of Commerce St. bridge on C. R. I. & P. Ry., spike in tie; rail painted "T. B. M. 12-414.0."	32–47–15.6	96–48–42.7	2620 to T. B. M. 11
413.764 T. B. M. 13	Commerce St. bridge, 1.2 miles northwest of, on C. R. I. & P. Ry., spike in top of pile in railway embankment, 6.7 ft. east of track, 12 inches above ground; painted "T. B. M. 13-413.8."	32–47–42.5	96–48–50.7	2796 to T. B. M. 12
414.264 B. M. 3	Commerce St. bridge, 1.6 miles northwest of, 200 ft. northwest of corner of Turtle Creek pumping station, 80 ft. east of main line of C. R. I. & P. Ry., 5 ft. north of railway crossing sign post; iron post stamped "No. 3-414.3."	32–48–00.6	96–49–01.6	2054 to T. B. M. 13
413.312 T. B. M. 14	Pumping plant, 0.5 mile northwest of, 250 ft. west of railway signboard, spike in tie of C. R. I. & P. Ry.; painted "T. B. M. 14-413.3."	32–48–16.0	96–49–28.4	2762 to B. M. 3
405.754 T. B. M. 15	Perkins, 300 ft. west of road crossing, 5 ft. south of small pig pen, spike in root of double pecan tree; painted "T. B. M. 15-405.8."	32–48–21.9	96–49–59.7	2736 to T. B. M. 14
406.277 T. B. M. 16	Perkins, 0.4 mile south of, 40 ft. east of Trinity River, spike in root of 6-inch hackberry; painted "T. B. M. 16-406.3."	32–48–01.9	96–50–09.5	2184 to T. B. M. 15
.... T. B. M. 17	Perkins, 0.4 mile south of, 50 ft. west of Trinity River, spike in root of 15-inch hackberry; blazed.	32–48–02.8	96–50–16.6	616 to T. B. M. 16
404.390 T. B. M. 18	Perkins, 0.7 mile southwest of, 360 ft. south of north fence in field, spike in root of 12-inch pecan in grove; painted "T. B. M. 18-404.4"	32–47–55.1	96–50–32.8	1585 to T. B. M. 17
405.927 B. M. 4	Dallas, about 3.0 miles west of, N. 30 E. of cement plant, 1097 ft. west of fence between fields, 125 ft. east of northwest fence corner of field, on edge of timber, 18 inches south of east and west fence; iron post stamped "No. 4-405.9"	32–47–48.6	96–50–46.4	1330 to T. B. M. 18
409.566 T. B. M. 19	Dallas, about 3.4 miles west of, 1200 ft. northwest of new house, 20 ft. south of newly cleared field, spike in root of 12-inch pecan in field; painted "T. B. M. 19-409.6"	32–47–42.4	96–51–12.3	2296 to B. M. 4
412.295 T. B. M. 20	Dallas, about 3.7 miles west of, 150 ft. north of fence, 100 ft. southeast of Trinity River, spike in root of 18-inch walnut in field; painted "T. B. M. 20-412.3"	32–47–33.1	96–51–40.0	2547 to T. B. M. 19
414.580 T. B. M. 21	Dallas, about 3.9 miles west of, 200 ft. southwest of ruins of old stone house, 50 ft. south of Trinity River, spike in 8-inch honey locust, white blazes; painted "T. B. M. 21-414.6"	32–47–15.8	96–51–59.6	2416 to T. B. M. 20

414.434 B. M. 5	Commerce St. bridge, about 4.1 miles west of, 0.7 mile northwest of house on hill, 0.5 mile north of Dallas-Eagleford road, 830 ft. west of lane, 252 ft. north of fence running west, 2 ft. west of fence between field and timber; iron post stamped "No. 5-414.5"	32–46–57.8	96–52–35.2	3533 to T. B. M. 21
416.755 T. B. M. 22	Texas Oil Co. plant, due north of, 150 ft. east of spur track to gravel pit, spike in root of 20-inch pecan, most northerly of 4 pecan trees in field; painted "T. B. M. 22-416.8"	32–47–02.3	96–53–08.5	2878 to B. M. 5
409.573 T. B. M. 23	Eagleford, about 2 miles northwest of, 36 ft. east of small creek, in open pasture, near artesian well, spike in root of 12-inch elm; painted "T. B. M. 23-409.6"	32–46–52.4	96–53–34.8	2461 to T. B. M. 22
411.890 T. B. M. 24	Eagleford, 1.5 miles north of, by fence between field and timber, spike in root of 24-inch elm; painted "T. B. M. 24-411.9"	32–47–00.0	96–54–08.1	2943 to T. B. M. 23
418.711 B. M. 6	Eagleford, 1.5 miles northwest of, 145 ft. south of southeast corner of approach to wagon bridge over Trinity River, 4 ft. east of east fence of wagon road, in field, 3.5 ft. northeast of 24-inch pecan; iron post stamped "No. 6-418.8"	32–47–01.3	96–54–50.8	3650 to T. B. M. 24
418.445 T. B. M. 25	Eagleford, 1.8 miles northwest of, 100 ft. east of fence, 50 ft. north of Trinity River, spike in root of 8-inch wild China tree; painted "T. B. M. 25-418.5"	32–47–08.5	96–55–10.5	1827 to B. M. 6
423.138 T. B. M. 26	Eagleford Bridge, 1.0 mile west of, on bank of slough between turnrow and fence, nail in root of 3-inch China tree; painted "T. B. M. 26-423.1"	32–46–26.1	96–55–40.5	4987 to T. B. M. 25
422.896 B. M. 7	Eagleford Bridge, about 1.6 miles west of, between slough and river, 150 ft. northwest of small house, 9 ft. east of narrow lane; iron post stamped "No. 7-422.9"	32–46–30.5	96–56–04.8	2119 to T. B. M. 26
(*No T. B. M.* 27) 424.246 T. B. M. 28	Eagleford Bridge, about 2 miles west of, 600 ft. west of bend in river, nail in root of 30-inch elm; painted "T. B. M. 28-424.2"	32–46–39.4	96–56–37.5	2934 to B. M. 7
427.677 T. B. M. 29	Eagleford Bridge, 2.5 miles west of, 200 ft. north of slough, 75 ft. west of fence, in newly cleared field, spike in 8-inch stump, 6 inches above the ground; painted "T. B. M. 29-427.7"	32–46–49.9	96–57–05.6	2621 to T. B. M. 28
427.381 T. B. M. 30	Eagleford Bridge, 3 miles west of, 40 ft. east of fence, in pasture, spike in root of 36-inch pecan; painted "T. B. M. 30-427.4"	32–46–51.1	96–57–34.9	2505 to T. B. M. 29
427.726 B. M. 8	Eagleford Bridge, 3.1 miles west of, 0.5 mile north of Trinity River, about 300 ft. southeast of Chas. Kune's house, 216 ft. south of county road, on land owned by E. T. Moore, 18 inches east of lot fence; iron post stamped "No. 8-427.7"	32–46–56.0	96–57–43.7	900 to T. B. M. 30
431.170 T. B. M. 31	Eagleford Bridge, 3.5 miles west of, spike in root of 24-inch post oak in fence line between timber and field; painted "T. B. M. 31-431.2"	32–46–31.4	96–57–59.4	2823 to B. M. 8
428.450 T. B. M. 32	Eagleford Bridge, 3.9 miles west of, about 0.25 mile northwest of small house, spike in root of 15-inch pecan; painted "T. B. M. 32-428.4"	32–46–23.5	96–58–24.2	2259 to T. B. M. 31
430.304 T. B. M. 33	Eagleford Bridge, 4 miles west of, in timber, 250 ft. west of fence by trail, spike in root of 18-inch elm; painted "T. B. M. 33-430.3"	32–46–07.7	96–58–31.6	1714 to T. B. M. 32

RESULTS OF PRIMARY TRAVERSE ANE LEVELING—Continued.

From Dallas, along Trinity River, via Eagle Ford, Grand Prairie and Tarrant to Fort Worth; and northeast along T. & P. Ry. to Boons Triangulation Station, near Keller—Continued.

Elevation above Sea Level	Description of Benchmark	Latitude	Longitude	Distanee to Point Indicated
Feet		° ′ ″	° ′ ″	*Feet*
430.592 T. B. M. 34	Eagleford Bridge, 4.5 miles west of, 500 ft. north of Horseshoe Club House, 400 ft. north of fence by slough, spike in root of tall, straight, 15-ineh elm; painted "T. B. M. 34-430.6"	32–45–49.4	96–58–51.2	2497 to T. B. M. 33
434.634 B. M. 9	Grand Prairie Bridge, about 0.8 mile east of, 0.2 mile west of Horseshoe Club House, about 1000 ft. north of river, 50 ft. east of gate, 12 inches north of south fence of Club House road; iron post stamped "No. 9-434.6"	32–45–46.8	96–59–08.6	1500 to T. B. M. 34
436.253 B. M. 10	Grand Prairie Bridge, about 0.4 mile north of, east side of Grand Prairie-Sowers road and north of road to Horseshoe Club Lake, 3 ft. from fence corner, in field; iron post stamped "No. 10-436.3"	32–45-47.4	96–59–41.3	2795 to B. M. 9
438.490 T. B. M. 35	Grand Prairie Bridge, about 0.7 mile northwest of, 800 ft. north of road, 400 ft. south of timber. spike in root of 20-inch pecan, in field; painted "T. B. M. 35-438.5"	32–45–53.7	97–00–07.3	2306 to B. M. 10
443.300 T. B. M. 36	Grand Prairie Bridge, about 1.2 miles northwest of, 10 ft. southeast of southeast corner of old shanty, spike in root of 15-inch oak; painted "T. B. M. 36-443.3"	32–46–15.2	97–00–21.3	2478 to T. B. M. 35
439.253 T. B. M. 37	Grand Prairie Bridge, about 1.7 miles northwest of, 600 ft. north of river, spike in root of 24-inch elm; painted "T. B. M., 37-439.3"	32–46–28.5	97–00 47.8	2636 to T. B. M. 36
447.827 B. M. 11	Grand Prairie Bridge. about 2.2 miles northwest of, 110 ft. north of river, 300 ft. northwest of L. K. Fulbrights' house, on Page place, 300 ft. south of old log house in field, 110 ft. east of bend north in road, 2.4 ft. north of south fence of Shady Grove road; iron post stamped "No. 11-447.8"	32–46–39.6	97–00–50.4	1145 to T. B. M. 37
453.636 T. B. M. 38	Grand Prairie Bridge. about 2.7 miles northwest of. 400 ft. south of fence, spike in root of 12-inch blackjack; painted "T. B. M. 38-453 6"	32–47–03.6	97–00–58.4	2517 to B. M. 11
454.695 T. B. M. 39	Grand Prairie Bridge, about 3.2 miles northwest of, 60 ft. north of slough, spike in root of 20-inch mulberry; painted "T. B. M. 39-454.7"	32–47–19.5	97–01–32.5	3322 to T. B. M. 38
449.287 T. B. M. 40	Grand Prairie Bridge, about 3.7 miles northwest of; level benchmark is 25.4 ft. N., 8° 30′ W., spike in root of 24-inch pecan, in field; painted "T. B. M. 40-449.3"	32–47–28.3	97–01–50.8	1800 to T. B. M. 39
498.474 T. B. M. 41	Grand Prairie Bridge, about 4.2 miles northwest of, 300 ft. southeast of small blue house, 25 ft. west of narrow lane, spike in root of 15-inch post oak; level benchmark, nail in tree 300 ft. southeast of T. B. M. 41, by fence line between field and timber.	32–48–00.5	97–01–46.0	3286 to T. B. M. 40
483.699 B. M. 12	Dallas-Tarrant Co. Line, 850 ft. west of County road, 16.6 ft. north of milepost "12" from northwest corner of Dallas County, 15 inehes south of fence; iron post stamped "No. 12-483.7"	32–48–26.2	97-02–03.8	3006 to T. B. M. 41

516.061 T. B. M. 42	County Line, 0.5 mile west of, on high ground, 0.75 mile southeast of house, 20 ft. east of private road, spike in root of 12-inch oak; painted "T. B. M. 42-516.1"	32–48–35.6	97–02–16.1	1417 to B. M. 12
450.290 T. B. M. 43	County Line, 0.8 mile west of, 160 ft. northeast of bend in river, 100 ft. south of high ridge, 12 ft. north of wood road, spike in root of dead oak; painted "T. B. M. 43-450.3"	32–48–33.1	97–02–30.2	1230 to T. B. M. 42
445.667 T. B. M. 44	County Line, 1.2 miles west of, 400 ft. west of big bend in river, spike in root of 24-inch elm; painted "T. B. M. 44-445.7"	32–48–49.9	97–03–04.8	3400 to T. B. M. 43
465.104 T. B. M. 20X	County Line, 2 miles west of, about 1000 ft. south of small house on hill, 300 ft. north small creek, spike in root of 12-inch elm; painted "T. B. M. 20-465.1"	32–48–36.0	97–03–59.1	4843 to T. B. M. 44
455.972 B. M. 13	Tarrant, 1.5 miles southeast of, 400 ft. northwest of Lower Dalton Crossing over Trinity River, 18 inches north of south fence to road; iron post stamped "No. 13-456.0"	32–48–01.8	97–03–59.7	3457 to T. B. M. 20X
456.008 T. B. M. 19X	Lower Dalton Crossing, 0.3 mile southwest of, 1100 ft. northeast of implement shed, spike in root of 24-inch pecan, in field; painted "T. B. M. 19-456.0"	32–47–57.0	97–04–13.5	1271 to B. M. 13
456.734 T. B. M. 18X	Lower Dalton Crossing, 0.8 mile southwest of, 50 ft. south of timber, spike in root of one of three dead trees at south end of fence; painted "T. B. M. 18-456.7"	32–47–44.3	97–04–37.6	2425 to T. B. M. 19X
460.757 T. B. M. 17X	Silver Lake, about 0.5 mile south of, at northernmost point of timber south of field, spike in root of 5-inch elm; painted "T. B. M. 17-460.8"	32–47–41.0	97–05–23.7	3950 to T. B. M. 18X
461.196 B. M. 24	Arlington, 4 miles north of, 2 miles southwest of Tarrant, 0.5 mile north of bridge over Trinity River, 21 ft. north of wood road, 18 inches east of west fence line to Arlington-Grapevine road; iron post stamped "No. 24-461.2"	32–47–44.9	97–06–00.3	3150 to T. B. M. 17X
.... T. B. M. 16.5X	Arlington, 5 miles north of, 1 mile southwest of Tarrant, crossing of wagon road and C. R. I. & P. Ry., center of road and track.	32–48–30.6	97–06–00.0	4613 to B. M. 24
463.719 T. B. M. 16X	Arlington-Grapevine road, 0.6 mile west of, 200 ft. west of fence running north, spike in root of 12-inch hackberry, in fence line between field and timber; painted "T. B. M. 16-463.7"	32–47–52.0	97–06–40.5	3497 to B. M. 24
465.490 T. B. M. 15X	Arlington-Grapevine road, 1.1 miles west of, 0.25 mile east of log barn in field, spike in root of 20-inch walnut by turnrow; painted "T. B. M. 15-465.5"	32–47–54.1	97–07–12.9	2775 to T. B. M. 16X
470.548 T. B. M. 14X	Bedford road, 0.6 mile east of, 100 ft. north of river, 2 ft. west of fence between fields, spike in root of 3-inch elm; painted "T. B. M. 14-470.5"	32–47–49.9	97–07–55.0	3618 to T. B. M. 15X
470.142 T. B. M. 13X	Bedford road, 0.3 mile east of, 15 ft. south of fence corner, 12 ft. northwest of river bank, spike in root of dead tree; painted "T. B. M. 13-470.1"	32–47–36.9	97–08–17.1	2296 to T. B. M. 14X
474.478 B. M. 25	Arlington, 4 miles northwest of, 34 ft. northwest of northwest corner of bridge over Trinity River, 18 inches east of west fence of Bedford road; iron post stamped "No. 25-474.5"	32–47–18.5	97–08–25.6	1998 to T. B. M. 13X
471.204 T. B. M. 12X	Bedford road, about 0.5 mile west of, 1000 ft. north of timber, 16 ft. west of slough in field, spike in root of 36-inch cottonwood; painted "T. B. M. 12-471.2"	32–47–05.3	97–08–59.6	3189 to B. M. 25

RESULTS OF PRIMARY TRAVERSE AND LEVELING—Continued.

From Dallas, along Trinity River, via Eagle Ford, Grand Prairie and Tarrant to Fort Worth; and northeast along T. & P. Ry. to Boons Triangulation Station near Keller—Continued.

Elevation above Sea Level	Description of Benchmark	Latitude	Longitude	Distance to Point Indicated
Feet		° ′ ″	° ′ ″	*Feet*
473.435 T. B. M. 11X	Bedford road, 1 mile west of, 300 ft. south of small house, 23 ft. east of road, spike in root of 24-inch pecan; painted "T. B. M. 11-473.4"	32–46–52.1	97–09–33.6	3193 to T. B. M. 12X
474.225 T. B. M. 10X	Bedford road, 1.4 miles west of, spike in one of three small elms used as fence corner; painted "T. B. M. 10-474.2"	32–46–47.6	97–09–54.2	1810 to T B. M. 11X
482.439 B. M. 27	Arlington, 7 miles northwest of, 60 ft. south of Randal's Mill Bridge over Trinity River, 18 ft. northeast of L. C. McPike's house on R. A. Randal's land, 2 ft. north of fence to public road; iron post stamped "NO. 27-482.4"	32–46–52.2	97–10–42.9	4190 to T. B. M. 10X
484.564 T. B. M. 1	Randal's Mill, 0.5 mile northwest of, in edge of timber next to field, spike in root of 24-inch elm; painted "T. B. M. 1-484.6"	.2–47–15.7	97–10–57.9	2694 to B. M. 27
484.985 T. B. M. 2	Randal's Mill, 1.0 mile northwest of, 100 ft. north of river, 20 ft. west of fence between field and timber, spike in root of 12-inch elm; painted "T. B. M. 2-485.0"	32–47–25.1	97–11–26.2	2595 to T. B. M 1
487.448 T. B. M. 3	Randal's Mill, 1.5 miles northwest of, about 5000 ft. south of C. R. I. & P. Ry., spike in 20-inch hackberry in fence between timber and field, painted "T. B. M. 3-487.4"	32–47–42.7	97–11–50.2	2708 to T. B. M. 2
487.962 B. M. 28	Randal's Mill, 2 miles northwest of, 0.5 mile south of trestle on C. R. I. & P. Ry., 0.5 mile southeast of Mr. Parker's house, 225 ft. north of timber, 1.9 ft. east of fence between fields, on Parker's east line, iron post stamped "No. 28-488.0"	32–47–55.3	97–12–14.7	2450 to T. B. M. 3
492.296 T. B. M. 4	Randal's Mill, 2.5 miles northwest of, 1200 ft. south of house, spike in root of 36-inch lone pecan in field; painted "T. B. M. 4-492.3"	32–47–46.9	97–12–38.0	2156 to B. M. 28
489.999 T. B. M. 5	Ray Crossing, 1 mile northeast of, on side of hill in edge of small clear strip in timber, spike in root of 12-inch post oak; painted "T. B. M. 5-490.0"	32–47–21.8	97–12–44.7	2601 to T. B. M. 4
488.916 T. B. M. 6	Ray Crossing, 0.5 mile northeast of, 100 ft. northwest of slough, spike in root of 6-inch ash in timber; painted "T. B. M. 6-488.9"	32–47–02.8	97–12–55.3	2124 to T. B. M. 5
492.780 B. M. 29	Ft. Worth, 5.5 miles northeast of, 450 ft. north of bridge over Trinity River known as Ray Crossing, 2 ft. west of east fence to road; iron post stamped "No. 29-492.8"	32–46–47.1	97–13–17.5	2469 to T. B. M. 6
509.081 T. B. M. 7	Ray Crossing, 0.5 mile northwest of, 500 ft. west of public road, spike in root of 30-inch post oak in edge of timber; painted "T. B. M. 7-509.1"	32–47–08.7	97–13–22.1	2219 to B. M. 29
494.690 T. B. M. 8	Ray Crossing, 1 mile northwest of, 0.25 mile northwest of barn in field, spike in root of 15-inch elm in fence line between fields; painted "T. B. M. 8-494.7"	32–47–13.3	97–13–52.1	2600 to T. B. M. 7

493.751 T. B. M. 9	Ray Crossing, 1.5 miles northwest of, spike in fence post where fence crosses pipe line; not good for levels. Level benchmark is 20 ft. northeast of T. B. M. 9, spike in 20-inch pecan; painted "T. B. M. 493.8"	32–47–13.5	97–14–18.3	2235 to T. B. M. 8
503.312 B. M. 30	Ft. Worth, 4 miles northeast of, 250 ft. east of bridge No. 616.8 of C. R. I. & P. Ry. 75 ft. south of track, on right of way, 5 ft. east and 1.9 ft. north of fence stamped "No. 30-503.3"	32–47–22.2	97–14–46.3	2549 to T. B. M. 9
503.870 T. B. M. 10	Ft. Worth, about 3.8 miles northeast of, 0.8 mile north of river, 80 ft. west of fence, spike in root of 30-inch elm standing alone in field; painted "T. B. M. 10-503.9"	32–46–57.7	97–15–04.0	2896 to B. M. 30
509.459 T. B. M. 11	Wright Crossing, about 1.5 miles northeast of, 0.25 mile north of river, 30 ft. south of section corner-stone in lane east and west, spike in root of 18-inch elm in fence line to private road; painted "T. B. M. 11-509.5"	32–46–48.3	97–15–30.1	2425 to T. B. M. 10
516.897 T. B. M. 12	Wright Crossing, about 1 mile north of, 600 ft. east of C. R. I. & P. Ry., 500 ft. north of river, spike in root of 6-inch elm in south fence of road; painted "T. B. M. 12-516.9"	32–46–48.6	97–15–59.7	2521 to T. B. M. 11
509.262 T. B. M. 13	Wright Crossing, about 0.6 mile north of, 490 ft. south of C. R. I. & P. Ry., spike in root of 40-inch post oak in road; painted "T. B. M. 13-509.3"	32–46–36.1	97–16–25.0	2503 to T. B. M. 12
504.303 B. M. 31	Ft. Worth, 3 miles east of, 804 ft. west of bridge over Trinity River known as Wright's Crossing, 1.8 ft. south of north fence of road; iron post stamped "No. 31-504.3"	32–45–55.9	97–16–26.4	4062 to T. B. M. 13
508.725 T. B. M. 14	Wright's Crossing, 0.5 mile southwest of, 0.5 mile north of river, 2000 ft. south of road, 4 ft. east of fence, spike in root of 12-inch double elm; painted "T. B. M. 14-508.7"	32–45–33.9	97–16–49.5	2970 to B. M. 31
512.554 T. B. M. 15	Wright's Crossing, 1 mile southwest of, on north bank of river, spike in root of 10-inch stump, 3 ft. northeast of 15-inch hackberry; painted "T. B. M. 15-512.6"	32–45–21.5	97–17–19.5	2850 to T. B. M. 14
554.859 T. B. M. 16	Ft. Worth, 1.2 miles southeast of, spike in root of 24-inch cottonwood in street east and west; painted "T. B. M. 16-554.9"	32–45–36.0	97–18–03.6	4044 to T. B. M. 15
530.634 B. M. 32	Ft. Worth, 238 ft. east of bridge over Trinity River on East First St., 0.7 ft. north of north fence to road on property belonging to A. L. Hightower; iron post stamped "No. 32-530.6"	32–45–54.6	97–18–39.7	3606 to T. B. M. 16
521.215 T. B. M. 17	Riverside Bridge, 0.5 mile northwest of, 500 ft. west of levee, 60 ft. east of fence, spike in root of 6-inch hackberry; painted "T. B. M. 17-521.2"	32–46–16.8	97–19–05.7	3159 to B. M. 32
521.080 T. B. M. 18	Riverside Bridge, 1 mile northwest of, 100 ft. west of levee, 6 ft. east of fence, spike in root of 30-inch elm; painted "T. B. M. 18-521.1"	32–46–34.4	97–19–26.6	2517 to T. B. M. 17
538.292 B. M. 33	Ft. Worth, 88 ft. east of Ft. Worth & Denver Ry., 57 ft. south of south pier of C. R. I. & P. Ry. bridge over Trinity River, and 7 ft. west of track, on top of levee; iron post stamped "No. 33-538.3"	32–46–52.9	97–20–04.1	3706 to T. B. M. 18
.... T. B. M. 19	Tarrant County Courthouse, 1 mile north of, 150 ft. east of levee, spike in root of 18-inch elm in pasture.	32–46–32.4	97–20–21.5	2547 to B. M. 33

RESULTS OF PRIMARY TRAVERSE AND LEVELING—Continued.

From Dallas, along Trinity River, via Eagle Ford, Grand Prairie and Tarrant to Fort Worth; and northeast along T. & P. Ry. to Boons Triangulation Station, near Keller—Continued.

Elevation above Sea Level	Description of Benchmark	Latitude	Longitude	Distance to Point Indicated
Feet		° ′ ″	° ′ ″	*Feet*
T. B. M. 20	Ft. Worth, spike in telephone pole, opposite No. 803 Samuels Ave., west side of street	32–46–08.3	97–19–49.9	3639 to T. B. M. 19
533.230 B. M. 34	Ft. Worth, about 2500 ft. north of Tarrant County courthouse, 1000 ft. north of bridge over Trinity River, in line of telephone poles, west side of North Main Street, 21 ft east of fence; iron post stamped "No. 34-533.2"	32–45–43.8	97–20–11.0	3067 to T. B. M. 20
531.808 T. B. M. 21	Ft. Worth, on North Main St., 4000 ft. north of river bridge, spike in telephone pole in street; painted "T. B. M. 21-531.8"	32–46–10.6	97–20–29.9	3160 to B. M. 34
Boons Triangulation Station	In Tarrant County, Texas, about 14 miles north of Ft. Worth on the middle one of three wooded knolls, one-fourth mile east of Mr. Boons' residence and 3 miles south of Keller. Instrument elevated 24 ft. Permanent mark: stone marked with a cross and U. S. G. S. (See p. 208, U. S. G. S. Bul. 122.)	32–55–05.62 (corrected)	97–16–42.17 (corrected)	57466 to T. B. M. 21
	From B. M. 6 near Eagle Ford Bridge over Trinity River, east along pike to B. M. 2 at Dallas.			
.... B. M. 6.5	Eagleford, 1.3 miles northwest of, 1130 ft. south of bridge over Trinity River, about 70 ft. northeast of small house, 29 ft. north of cross fence, in public road 18 inches east of west fence line; iron post not stamped.	32–46–51.4	96–54–50.8	986 to B. M. 6
420.171 T. B. M. 1B	Eagleford, 1.5 miles northeast of, north side Dallas-Eagleford road, spike in base of corner post of fence by gate; painted "T. B. M. 1B-420.2"	32–46–41.9	96–53–46.8	5801 to B. M. 6
418.938 B. M. 35	Dallas, about 5 miles west of, 0.7 mile northwest of Texas Oil Co.'s plant, 300 ft. southwest of small cottage, 12 inches south of south fence to Dallas-Eagelford road; iron post stamped "No. 35-418.9"	32–46–42.9	96–53–16.5	2587 to T. B. M. 1B
422.870 T. B. M. 2B	Dallas, about 4.5 miles west of, 300 ft. east of store, spike in telephone pole; painted "T. B. M. 2B-422.9"	32–46–43.3	96–52–52.5	2055 to B. M. 35
440.811 T. B. M. 3B	Dallas, about 4 miles west of, spike in root of double locust, south side of road; painted "T. B. M. 3B-440.8"	32–46–42.5	96–52–23.6	2470 to T. B. M.2B
462.395 B. M. 35.1	On highest point of road over Hasty Hill, 4 miles west of Dallas, south side of road; iron post stamped "No. 35.1-462.4"	32–46–42.1	96–52–13.4	870 to T. B. M. 3B
426.966 B. M. 36	Dallas, about 3.5 miles west of, about 100 ft. northwest of public watering trough by store, northside of road in line of telephone poles; iron post stamped "No. 36-427.0"	32–46–42.8	96–51–55.5	1529 to B. M. 35.1
415.274 T. B. M. 4B	Dallas, about 3 miles west of, spike in telephone pole, north side of Dallas-Eagleford Pike; painted "T. B. M. 4B-415.3"	32–46–42.6	96–51–24.2	2674 to B. M. 36

416.176 T. B. M. 5B	Dallas, about 2.5 miles west of, on Dallas-Eagleford Pike, 12 ft. east of lane by store, spike in root of 18-inch oak; painted "T. B. M. 5B-416.2"	32–46–41.7	96–50–51.8	2759 to T. B. M. 4B
414.076 B. M. 37	Dallas, about 2 miles west of, on south side of Dallas-Eagleford Pike, 200 ft. west of store, at intersection with road north, 12 inches north of fence; iron post stamped "No. 37-414.1"	32–46–41.7	96–50–22.5	2499 to T. B. M. 5B
415.154 T. B. M. 6B	Dallas, about 1.5 miles west of, 250 ft. east of store, spike in fence post on north side of Dallas-Eagleford Pike; painted "T. B. M. 6B-415.2"	32–46–42.3	96–49–53.0	2516 to B. M. 37
409.204 T. B. M. 7B	Dallas, 1 mile west of, spike in south pile of bent of T. & P. Ry. crossing over Dallas-Eagleford Pike; painted "T. B. M. 7B-409.2"	32–46–36.0	96–49–27.3	2286 to T. B. M. 6B
404.180 B. M. 38	West Dallas, at northeast corner of intersection of Eagleford Pike and West Commerce Street, 5000 ft. west of Dallas County courthouse; iron post stamped "No. 38-404.2"	32–46–29.2	96–49–21.3	860 to T. B. M. 7B 3012 to B. M. 2
From B. M. 6 near Eagle Ford Bridge over Trinity River, northeast to Lively Switch; thence along Rock Island Railroad southeast to T. B. M. 15 at Perkins Switch, one and one-half miles northwest of Dallas.				
415.591 T. B. M. 1C	Eagleford Bridge, 0.5 mile north of, spike in root of 12-inch elm on west side of Eagleford-Coppell road, corner of wooded pasture; painted "T. B. M. 1C-415.6"	32–47–29.0	96–55–01.5	2942 to B. M. 6
416.148 T. B. M. 2C	Eagleford Bridge, 1 mile north of, 700 ft. east of farm house on hill, spike in telephone pole, east side of Eagleford-Coppell road; painted "T. B. M. 2C-416.2"	32–47–52.1	96–55–05.7	2362 to T. B. M. 1C
411.665 B. M. 39	Eagleford Bridge, about 1.5 miles northeast of, 2450 ft. northeast of Coppell road, 135 ft. west of slough, on east and west fence line; iron post stamped "No. 39-411.7"	32–47–55.2	96–54–37.3	2452 to T. B. M. 2C
412.572 T. B. M. 3C	Eagleford Bridge, about 2 miles northeast of, 75 ft. east of drainage canal, spike in root of 16-inch elm in fence line, east side of lane; painted "T. B. M. 3C-412.6"	32–47–58.5	96–54–01.6	3062 to B. M. 39
409.332 T. B. M. 4C	Elm Fork, about 2.5 miles west of, 1725 ft. south of C. R. I. & P. Ry., 75 ft. east of fence, spike in root of 30-inch double pecan; painted "T. B. M. 4C-409.3"	32–48–32.8	96–54–02.3	3467 to T. B. M. 3C
414.783 B. M. 40	Dallas, about 6 miles northwest of, 300 ft. east of west end of switch of C. R. I. & P Ry., 50 ft. north of signal tower, 12 inches south of right of way fence; iron post stamped "No. 40-414.8"	32–48–49.9	96–53–50.2	2015 to T. B. M. 4C
409.742 T. B. M. 5C	Dallas, about 5.5 miles northwest of, 75 ft. north of C. R. I. & P. Ry. track, 25 ft. north of fence, spike in root of 24-inch pecan in field at foot of hills; painted "T. B. M. 5C-409.7"	32–48–49.4	96–53–16.3	2887 to B. M. 40
409.330 T. B. M. 6C	Dallas, about 5 miles northwest of, 0.5 mile east of hills, spike in telephone pole on right of way of C. R. I. & P. Ry., 40 ft. south of track; painted "T. B. M. 6C-409.3"	32–48–47.8	96–52–46.8	2528 to T. B. M. 5C
404.933 B. M. 41	Dallas, 4.5 miles northwest of, 250 ft. west of highway bridge over creek, by north fence of C. R. I. & P. Ry. right of way, south side of pike; iron post stamped "No.41-404.9"	32–48–48.4	96–52–15.9	2640 to T. B. M. 6C
406.871 T. B. M. 7C	Dallas, 4 miles northwest of, 100 ft. south of bank of Elm Fork of Trinity River, 2 ft. north of fence, spike in 12-inch China tree; painted "T. B. M. 7C-406.9"	32–48–54.6	96–51–44.8	2730 to B. M. 41

RESULTS OF PRIMARY TRAVERSE AND LEVELING—Continued.

From B. M. 6 near Eagle Ford Bridge over Trinity River, northeast to Lively Switch; thence along Rock Island Railroad southeast to T. B. M. 15 at Perkins Switch, one and one-half miles northwest of Dallas—Continued.

Elevation above Sea Level	Description of Benchmark	Latitude	Longitude	Distance to Point Indicated
Feet		° ′ ″	° ′ ″	*Feet*
418.138 T. B. M. 8C	Dallas, about 3.5 miles northwest of, 200 ft. east of bridge over Elm Fork of Trinity River, 100 ft. south of road, spike in root of 8-inch post oak; painted "T. B. M. 8C-418.1"	32–49–02.0	96–51–20.0	2250 to T. B. M. 7C
401.668 B. M. 42	Dallas, about 3 miles northwest of, 0.5 mile southeast of pumping station, 3 ft. south of fence to C. R. I. & P. Ry., right of way; iron post stamped "No. 42-401.7"	32–48–43.3	96–50–59.0	2609 to T. B. M. 8C
413.986 T. B. M. 9C	Perkins switch, west end of, spike in telephone pole; painted "T. B. M. 9C-414.0"	32–48–31.4	96–50–21.7	3368 to B. M. 42

From Dallas, along Trinity River, via Miller and Lakewood, to U. S. Lock and Dam No. 1; and return along north side of river to point of beginning.

Elevation above Sea Level	Description of Benchmark	Latitude	Longitude	Distance to Point Indicated
428.681 B. M. 1	Dallas, 2.3 miles southeast of, 1100 ft. southeast of Santa Fe bridge, No. 6110, across Trinity River, 49 ft. west of Santa Fe Ry., north side of Hutchings road, 3 ft. inside fence corner, in Mr. Warren's pasture; iron post stamped "No. 1-428.7"	32–44–54.1	96–47–50.9	....
395.727 T. B. M. 1A	Dallas, 2.8 miles southeast of, 200 ft. north of shed, 180 ft. east of small creek, spike in root of 12-inch elm; painted "T. B. M. 1-395.7"	32–44–54.8	96–47–19.1	2714 to B. M. 1
390.674 T. B. M. 2A	Dallas, 3.1 miles southeast of, 620 ft. west of M. K. & T. trestle through Trinity bottoms, spike in root of 30-inch dead elm; painted "T. B. M. 2-390.7"	32–44–49.0	96–46–54.2	2208 to T. B. M. 1A
391.677 T. B. M. 3A	Dallas, 3.6 miles southeast of, 15 ft. north of fence, spike in root of 15-inch elm; painted "T. B. M. 3-391.7"	32–44–40.0	96–46–28.1	2409 to T. B. M. 2A
389.393 T. B. M. 4A	Dallas, 4 miles southeast of, 150 ft. north of slough, spike in root of 18-inch elm; painted "T. B. M. 4-389.4"	32–44–23.4	96–46–18.9	1853 to T. B. M. 3A
390.907 T. B. M. 5A	Dallas, 4.3 miles southeast of, 500 ft. south of heavy timber, 100 ft. north of field fence, spike in root of 4-inch dead locust; painted "T. B. M. 5-390.9"	32–44–09.4	96–45–58.5	2243 to T. B. M. 4A
393.858 B. M. 18	Dallas, about 4.8 miles southeast of, 0.5 mile west of Dallas-Hutchings bridge over Trinity, 700 ft. west of old wagon bridge, 125 ft. south of river, 4 ft. inside northeast corner of field, on land owned by Jake Mantell; iron post stamped "No. 18-393.9"	32–43–43.4	96–45–48.2	2778 to T. B. M. 5A
386.571 T. B. M. 6A	Dallas, 5 miles southeast of, about 200 ft. east of Dallas-Hutchings bridge, spike in root of 20-inch leaning hackberry; painted "T. B. M. 6-386.6"	32–43–32.3	96–45-26.6	2151 to B. M. 18
394.000 T. B. M. 7A	Dallas, 5.8 miles southeast of, 0.3 mile east of H. & T. C. Ry., 6 ft. east of drain ditch from gravel pit, spike in root of 6-inch mesquite; painted "T. B. M. 7-394.0"	32–43–22.9	96–44–55.1	2858 to T. B. M. 6A

390.297 B. M. 19	Dallas, about 6.5 miles southeast of, 1.2 miles east of H. & T. C. Ry. bridge over Trinity River, 0.2 mile west of river, 15 ft. north of bend in outlet canal to slough, 4 ft. west of corner post to three-way fence between field and timber; iron post stamped "No. 19-390.3"	32–43–12.9	96–44–11.6	3852 to T. B. M. 7A
399.403 T. B. M. 9A	Dallas, 7 miles southeast of, 6 ft. east of fence between field and timber, spike in dead stump; painted "T. B. M. 9-399.4"	32–42–40.7	96–44–30.2	3619 to B. M. 19
387.830 T. B. M. 10A	Dallas, 7.5 miles southeast of, spike in post farthest east of east sluice-gate, in dyke running east and west, north of Lakewood Club Lake; painted "T. B. M. 10-387.8"	32–42–20.0	96–44–23.8	2166 to T. B. M. 9A
388.856 T. B. M. 11A	Dallas, 8 miles southeast of, on spillway of sluice-gates to club lake at Lakewood; painted "T. B. M. 11-388.9"	32–42–08.3	96–44–11.8	1558 to T. B. M. 10A
390.213 T. B. M. 12A	Dallas, about 8.5 miles southeast of, 100 ft. south of Trinity River, 10 ft. south of dyke, spike in root of 36-inch dead oak; painted "T. B. M. 12-390.2"	32–41–51.3	96–43–45.5	2833 to T. B. M. 11A
388.233 B. M. 20	Dallas, about 9 miles southeast of, 1 mile east of H. & T. C. Ry., 600 feet east of club lake at Lakewood, 1000 ft. south of Trinity River, 600 ft. north of low ridge, 12 inches west of east fence of field on land belonging to J. P. Grubbs; iron post stamped "No. 20-388.2"	32–41–42.6	96–43–20.9	2276 to T. B. M. 12A
385.288 T. B. M. 13A	Dallas, about 8.5 miles southeast of, 150 ft. west of fence corner, spike in telephone pole by south fence to lane east and west; painted "T. B. M. 13-385.3"	32–41–42.3	96–42–57.3	2015 to B. M. 20
385.349 T. B. M. 14A	Dallas, about 8.7 miles southeast of, 250 ft. west of and 100 ft. south of fences, spike in root of 30-inch pecan in field; painted "T. B. M. 14-385.3"	32–41–40.2	96–42–36.0	1833 to T. B. M. 13A
382.444 T. B. M. 15A	Dallas, about 9.3 miles southeast of, 4 ft. north of fence between fields, spike in root of 15-inch leaning elm; painted "T. B. M. 15-382.4"	32–41–14.8	96–42–22.0	2828 to T. B. M. 14A
383.181 T. B. M. 16A	Dallas, about 9.5 miles southeast of, spike in telephone pole, 6 ft. north of fence in timber; painted "T. B. M. 16-383.2"	32–41–28.4	96–41–55.7	2631 to T. B. M. 15A
385.996 B. M. 21	Dallas, about 9.9 miles southeast of, east side of river at Government lock and dam No. 1, 42 ft. east of lock, 15 ft. south of steps up stone wall, 18 inches west of wall; iron post stamped "No. 21-386.0"	32–41–35.1	96–41–27.5	2506 to T. B. M. 16A
425.226 T. B. M. 17A	Dallas, about 9.4 miles southeast of, spike in root of 24-inch elm on ridge; painted "T. B. M. 17-425.2"	32–42–03.8	96–41–40.0	3092 to B. M. 21
429.928 T. B. M. 18A	Dallas, about 8.7 miles southeast of, 30 ft. west of log house on hill, spike in root of quadruple dead oak, in small inclosure; painted "T. B. M. 18-429.9"	32–42–13.2	96–42–08.2	2586 to T. B. M. 17A
422.066 B. M. 22	Dallas, about 8.5 miles southeast of, 0.5 mile north of Trinity River, 0.2 mile south of lane, 125 ft. east of new cabin, 16 inches south of fence in field; iron post stamped "No. 22-422.1"	32–42–24.1	96–42–26.7	1929 to T. B. M. 18A
395.651 T. B. M. 19A	Dallas, about 7.9 miles southeast of, spike in root of 36-inch pecan in field by small creek; painted "T. B. M. 19-395.7"	32–42–37.0	96–42–57.8	2961 to B. M. 22

RESULTS OF PRIMARY TRAVERSE AND LEVELING—Continued.

From Dallas, along Trinity River, via Miller and Lakewood, to U. S. Lock and Dam No. 1 and return along north side of river to point of beginning—Continued.

Elevation above Sea Level	Description of Benchmark	Latitude	Longitude	Distance to Point Indicated
Feet		° ′ ″	° ′ ″	*Feet*
392.918 T. B. M. 20A	Dallas, about 7.5 miles southeast of, spike in root of 36-inch cottonwood standing alone in field; painted "T. B. M. 20-392.9"	32–42–51.3	96–43–19.3	2335 to T. B. M. 19A
400.804 B. M. 23	Dallas, about 7 miles southeast of, on Kirby's land, 500 ft. northeast of bend in river, 33 ft. southeast of red negro cabin, 12 ft. south of old shed, 18 inches west of fence by private road; iron post stamped "No. 23-400.8"	32–43–07.2	96–43–46.0	2790 to T. B. M. 20A
388.893 T. B. M. 21A	Dallas, about 6.7 miles southeast of, 1 mile south of Kirby's barn, spike in root of bois d'arc; painted "T. B. M. 21-388.9"	32–43–34.0	96–43–47.1	2704 to B. M. 23
396.520 T. B. M. 22A	Dallas, 6.6 miles southeast of, spike in fence post, south of Kirby's carriage shed; painted "T. B. M. 22-396.5"	32–44–18.6	96–43–36.4	4603 to T. B. M. 21A
389.851 B. M. 24	Dallas, 5 miles southeast of, 1.5 miles northeast of Dallas-Hutchings bridge across Trinity River, on Mrs. Taylor's land, in southeast corner of field next to timber, 5.2 ft. from corner post; iron post stamped "No. 24-389.8"	32–44–26.7	96–44–28.7	4543 to T. B. M. 22A
398.970 T. B. M. 23A	Dallas, about 5 miles southeast of, 20 ft. south of private road, 12 ft. north of fence, on Mrs. Taylor's land, spike in root of 12-inch blackjack; painted "T. B. M. 23-399.0"	32–44–18.1	96–44–51.8	2146 to B. M. 24
390.670 T. B. M. 24A	Dallas, 5.2 miles southeast of, north of Trinity River, spike in telephone pole 40 ft. east of H. & T. C. Ry. trestle (this point was reset 33 ft. northwest of calculated point); painted "T. B. M. 24-390.7"	32–43–53.1	96–45–18.8	3427 to T. B. M. 23A
392.196 T. B. M. 25A	Dallas, about 4.7 miles east of, 300 ft. south of fence between timber and pasture, 100 ft. northeast of Trinity River, spike in root of 15-inch hackberry; painted "T. B. M. 25-392.2"	32–44–15.1	96–45–52.6	3637 to T. B. M. 24A
396.595 T. B. M. 26A	Dallas, 4 miles east of, 850 ft. south of old railroad embankment, spike in root of 6-inch hackberry; painted "T. B. M. 26-396.6"	32–44–38.0	96–46–09.8	2748 to T. B. M. 25A
401.964 T. B. M. 27A	Dallas, 3.7 miles east of, spike in fence post on old railroad embankment; painted "T. B. M. 27-402.0"	32–45–03.5	96–46–24.3	2855 to T. B. M. 26A
408.162 T. B. M. 28A	Dallas, 3.6 miles southeast of, spike in northeast end of tie, M. K. & T. Ry.; side of rail painted "T. B. M. 28-408.2"	32–45–15.5	96–46–40.3	1827 to T. B. M. 27A 6407 to B. M. 1

From T. B. M. 4-C, about 7 miles northwest of Dallas, northward to Owens' Crossing on Elm Fork of Trinity River; thence down Elm Fork to Rock Island R. R. Bridge, and westward along railroad track to B. M. 40.

B. M. 43 417.206	Dallas, 7 miles nortwest of, 3100 ft. west of Norwood Flag Station, 150 ft. south of Rock Island R. R. track, at road corner, 2.5 ft. east of southwest corner post; iron post stamped "No. 43-417.2"	32–48–48.9	96–54–28.9	2789 to T. B. M. 4-C
T. B. M. 1-E 409.757	Norwood Flag Station, about 2000 ft. northwest of, 15 ft. southwest of corner to 3-way fence, in root of 15-inch elm tree by fence; nail.	32–49–05.5	96–54–11.8	2223 to B. M. 43
T. B. M. 2-E 407.885	Norwood Flag Station, about 1 mile north of, ½ mile south of Dallas-Grapevine road, in root of 12-inch Chittam tree in east and west fence line; nail.	32–49–29.7	96–53–43.7	3430 to T. B. M. 1-E
B. M. 44 412.637	Dallas, 8½ miles northwest of, 1½ mile west of Elm Fork on Dallas-Grapevine road, 82 ft. north of levee, north of road and west of lane, 1.7 ft. north of corner post; iron post stamped "No. 44-412.6"	32–49–46.2	96–53–43.5	1665 to T. B. M. 2-E
T. B. M. 3-E 423.594	Dallas-Grapevine road, ½ mile north of, 150 ft. southeast of small house, in root of 24-inch oak tree, in east and west lane; nail.	32–50–11.9	96–53–35.9	2681 to B. M. 44
T. B. M. 4-E 418.862	Dallas-Grapevine road, 1 mile north of, ¼ mile east of foot hills, in root of 12-inch pecan tree in edge of timber, 15 ft. east of field fence; nail.	32–50–34.4	96–53–56.5	2870 to T. B. M. 3-E
B. M. 45 433.712	Dallas, 10 miles northwest of, ¾ miles south of Elm Fork, ¼ mile east of Will Owens' house in lane running east, 2 ft. north of fence and old Bois d' Arc hedge; iron post stamped "No. 45-433.7"	32–50–38.2	96–54–38.0	3562 to T. B. M. 4-E
T. B. M. 5-E 427.158	Will Owens' house, about ¾ mile northeast of, in root of 6-inch Bois d'Arc tree at corner of fence and hedge; nail.	32–51–02.7	96–54–45.0	2549 to B. M. 45
B. M. 46 420.997	Dallas, 11 miles northwest of, 1¼ miles north of Will Owens' house, 25 ft. south of bank of Elm Fork, at old Owens' Crossing, in lane, 6 inches east of west fence; iron post stamped "No. 46-421.0"	32–51–20.3	96–54–56.9	2043 to T. B. M. 5-E
B. M. 47 414.149	Dallas, 10 miles northwest of, about 1000 ft. south of Elm Fork, about 1000 ft. north of small house, 19 ft. north of fence corner of lane and wagon road, 1.3 ft. west of fence; iron post stamped "No. 47-414.2"	32–51–04.8	96–54–25.8	3075 to B. M. 46
T. B. M. 6-E 415.202	In thicket of green briers, 600 ft. west of Elm Fork, in root of 6-inch hackberry tree; nail.	32–51–01.7	96–53–59.9	2239 to B. M. 47
T. B. M. 7-E 412.527	Winn's Lake, ½ mile northeast of, about 600 ft. west of Elm Fork, in base of stump of 40-inch pecan tree; nail.	32–50–41.8	96–53–27.2	3433 to T. B. M. 6-E

From T. B. M. 4-C, about 7 miles northwest of Dallas, northward to Owens' Crossing on Elm Fork of Trinity River; thence down Elm Fork to Rock Island R. R. Bridge, and westward along railroad track to B. M. 40.

Elevation above Sea Level	Description of Benchmark	Latitude	Longitude	Distance to Point Indicated
Feet		° ′ ″	° ′ ″	*Feet*
T. B. M. 8-E 409.823	Winn's Lake, ½ mile east of, about 1000 ft. north of line of telephone poles, in root of 4-inch hackberry tree, in open pasture; nail.	32–50–21.0	96–53–01.3	3055 to T. B. M. 7-E
T. B. M. 9-E 405.309	On Dallas-Grapevine County road, 1¼ miles northwest of county bridge over Elm Fork, 900 ft. north of roadway, 200 ft. west of fence; nail in root of 18-inch hackberry tree.	32–49–52.5	96–52–42.7	3291 to T. B. M. 8-E
B. M. 48 406.083	On Dallas-Grapevine County road, 6 miles northwest of Dallas, 1 mile west of bridge over Elm Fork, 25 ft. west of fence corner, 1.3 ft. south of north fence line; iron post stamped "No. 48-406.1"	32–49–43.7	96–52–40.8	897 to T. B. M. 9-E
T. B. M. 10-E 407.656	Dallas-Grapevine road, ½ mile south of, in root of double elm tree 9 ft. west of wagon road; nail.	32–49–15.3	96–52–40.7	2870 to B. M. 48
Rock Island Ry. Bridge	Center of track at west end of Rock Island Ry. bridge over Elm Fork.	32–48–46.8	96–51–44.6	5590 to T. B. M. 10-E
Road crossing	Rock Island Ry. bridge, about ¾ mile west of, center of crossing of wagon road and railroad track.	32–48–47.6	96–52–23.4	3303 to Rock Island Bridge
Switch	Rock Island Ry. bridge, 1½ miles west of, center of track at east end of switch, opposite switch stand.	32–48–48.7	96–53–15.0	4403 to road crossing
Norwood Flag Station	Rock Island Ry. bridge, about 1¾ miles west of, center of track opposite Norwood Flag Station.	32–48–48.9	96–53–28.6	1160 to switch 1848 to B. M. 40

Intersected points near Dallas, not occupied. Each point sighted from at least three stations on the foregoing traverse lines.

Description of Point Sighted.	Latitude.	Longitude	Distances to Points Indicated.
	° ′ ″	° ′ ″	*Feet*
Center of water tower of Dallas Brewery, Dallas	32–47–02.6	96–48–32.5	1245 to T. B. M. 11 1578 to T. B. M. 12 6358 to B. M. 3
Center of chimney at city pumping station, Turtle Creek, Dallas	32–47–59.6	96–48–58.5	18380 to B. M. 35.1 25876 to T. B. M. 3-C 25837 to T. B. M. 1-B
Center of water tower in Oak Cliff, near south end of viaduct	32–45–13.9	96–48–36.0	3300 to T. B. M. 7 2305 to T. B. M. 9 12304 to T. B. M. 12
Center of cupola on Dallas County courthouse, Dallas	32–46–42.3	96–48–25.6	3948 to B. M. 2 1162 to T. B. M. 11 6694 to T. B. M. 9 9997 to T. B. M. 7

AZIMUTH MARKS.

From B. M. 2 (see page 59) to center of cupola on Dallas County courthouse, the true azimuth is 216° 47′ 03″.
" B. M. 6 (see page 61) to B. M. 6.5 (see page 66), the true azimuth is (pointing is due south) 0° 00′ 00″.
" B. M. 10 (see page 62) to B. M. 9 (see page 62), the true azimuth is 271° 07′ 31″.
" T. B. M. 16.5X (see page 63) to eastward, along center line of C. R. I. & P. Ry. track, the true azimuth is 254° 32′ 38″.
" T. B. M. 16.5X (see page 63) to westward, along center line of C. R. I. & P. Ry. track, the true azimuth is 74° 32′ 38″.
" B. M. 33 (see page 65) to center of cupola on Tarrant County courthouse, Ft. Worth, the true azimuth is 356° 24′ 44″.
Center of track, Rock Island Ry. (long tangent through Norwood Flag Station, see page 72), the true azimuth is 91° 25′ 35.0″.

DECLINATION OF THE MAGNETIC NEEDLE.

Observed during 1912 at the following points:

U. S. Lock and Dam No. 1,	Dallas Co.,	magnetic declination	—8° 45′ East.
T. B. M. 25-A,	"	" "	—8° 50′ "
City of Dallas,	"	" "	—8° 50′ "
B. M. 4,	"	" "	—8° 50′ "
B. M. 9,	"	" "	—8° 55′ "
B. M. 25,	Tarrant Co.,	" "	—9° 00′ "
Randal's Mill,	"	" "	—9° 00′ "
City of Ft. Worth,	"	" "	—9° 05′ "

TABLE 1.—Giving the cubic contents, costs, and equivalent borrow pits, of levees with varying heights and crowns, having side slopes 2 to 1.

Vertical Height	Crown Width	Base Width	Area of Cross-section	Cubic Yards of Embankment: Per 100 feet	Cubic Yards of Embankment: Per mile	Cost of Levee Per Mile: At 1c. per cu. yd.	At 2c. per cu. yd.	At 3c. per cu. yd.	At 4c. per cu. yd.	At 5c. per cu. yd.	At 6c. per. cu yd.	At 7c. per cu. yd.	At 8c. per cu. yd.	At 9c. per cu. yd.	Dimensions of the Equivalent Borrow Pit: Area of cross-section	Greatest depth	Top width
Feet	*Feet*	*Feet*	*Sq. Feet*	*Cu. Yds.*	*Cu. Yds*										*Sq. Feet*	*Feet*	*Feet*
1	4	8	6	22	1173	$ 11.73	$ 23.46	$ 35.19	$ 46.92	$ 58.65	$ 70.38	$ 82.11	$ 93.84	$ 105.57	6.4	2.0	6
1½	4	10	10.5	39	2053	20.53	41.06	61.59	82.12	102.65	123.18	143.71	164.24	184.77	11.2	2.7	8
2	4	12	16.0	59	3129	31.29	62.58	93.87	125.16	156.45	187.74	219.03	250.32	281.61	17.1	3.01	10
2½	4	14	22.5	83	4400	44.00	88.00	132.00	176.00	220.00	264.00	308.00	352.00	396.00	24.0	3.3	12
3	4	16	30.0	111	5867	58.67	117.34	176.01	234.68	293.35	352.02	410.69	469.36	528.03	32.0	3.6	15
3½	4	18	38.5	143	7529	75.29	150.58	225.87	301.16	376.45	451.74	527.03	602.32	677.61	41.1	3.8	17
4	4	20	48.0	178	9387	93.87	187.74	281.61	375.48	469.35	563.22	657.09	750.96	844.83	51.2	4.1	20
4	6	22	56.0	207	10951	109.51	219.02	328.53	438.04	547.55	657.06	766.57	876.08	985.59	59.8	4.3	22
4½	6	24	67.5	250	13200	132.00	264.00	396.00	528.00	660.00	792.00	924.00	1,056.00	1,188.00	72.0	4.5	24
5	6	26	80.0	296	15644	156.44	312.88	469.32	625.76	782.20	938.64	1,095.08	1,251.52	1,407.96	85.4	4.8	27
5½	6	28	93.5	346	18284	182.84	365.68	548.52	731.36	914.20	1,097.04	1,279.88	1,462.72	1,645.56	99.8	5.1	30
6	6	30	108.0	400	21120	211.20	422.40	633.60	844.80	1,056.00	1,267.20	1,478.40	1,689.60	1,900.80	115.2	5.4	33
6	8	32	120.0	444	23467	234.67	469.34	704.01	938.68	1,173.35	1,408.02	1,642.69	1,877.36	2,112.03	128.0	5.6	35
6½	6	32	123.5	457	24151	241.51	483.02	724.53	966.04	1,207.55	1,449.06	1,690.57	1,932.08	2,173.59	131.8	5.7	36
6½	8	34	136.5	506	26693	266.93	533.86	800.79	1,067.72	1,334.65	1,601.58	1,868.51	2,135.44	2,402.37	145.6	5.9	38
7	6	34	140.0	518	27378	273.78	547.56	821.34	1,095.12	1,368.90	1,642.68	1,916.46	2,190.24	2,464.02	149.4	6.0	39
7	8	36	154.0	570	30116	301.16	602.32	903.48	1,204.64	1,505.80	1,806.96	2,108.12	2,409.28	2,710.44	164.3	6.3	42
7½	6	36	157.5	583	30800	308.00	616.00	924.00	1,232.00	1,540.00	1,848.00	2,156.00	2,464.00	2,772.00	168.1	6.3	42
7½	8	38	172.5	639	33733	337.33	674.66	1,011.99	1,349.32	1,686.65	2,023.98	2,361.31	2,698.64	3,035.97	184.1	6.6	45
8	6	38	176.0	652	34418	344.18	688.36	1,032.54	1,376.72	1,720.90	2,065.08	2,409.26	2,753.44	3,097.62	187.8	6.6	45
8	8	40	192.0	711	37547	375.47	750.94	1,126.41	1,501.88	1,877.35	2,252.82	2,628.29	3,003.76	3,379.23	204.9	6.9	48
8½	6	40	195.5	724	38231	382.31	764.62	1,146.93	1,529.24	1,911.55	2,293.86	2,676.17	3,058.48	3,440.79	208.6	6.9	48
8½	8	42	212.5	787	41556	415.56	831.12	1,246.68	1,662.24	2,077.80	2,493.36	2,908.92	3,324.48	3,740.04	226.7	7.2	51
9	6	42	216.0	800	42240	422.40	844.80	1,267.20	1,689.60	2,112.00	2,534.40	2,956.80	3,379.20	3,801.60	230.5	7.2	51
9	8	44	234.0	867	45760	457.60	915.20	1,372.80	1,830.40	2,288.00	2,745.60	3,203.20	3,660.80	4,118.40	249.7	7.5	54
9½	8	46	256.5	950	50160	501.60	1,003.20	1,504.80	2,006.40	2,508.00	3,009.60	3,511.20	4,012.80	4,514.40	273.7	7.8	57
10	8	48	280.0	1037	54756	547.56	1,095.12	1,642.68	2,190.24	2,737.80	3,285.36	3,832.92	4,380.48	4,928.04	298.8	8.1	60
10½	8	50	304.5	1128	59547	595.47	1,190.94	1,786.41	2,381.88	2,977.35	3,572.82	4,168.29	4,763.76	5,359.23	324.9	8.4	63
11	8	52	330.0	1222	64533	645.33	1,290.66	1,935.99	2,581.32	3,226.65	3,871.98	4,517.31	5,162.64	5,807.97	352.1	8.8	67
11½	8	54	356.5	1320	69716	697.16	1,394.32	2,091.48	2,788.64	3,485.80	4,182.96	4,880.12	5,577.28	6,274.44	380.4	9.1	70
12	8	56	384.0	1422	75093	750.93	1,501.86	2,252.79	3,003.72	3,754.65	4,505.58	5,256.51	6,007.44	6,758.37	409.7	9.4	73
12	10	58	408.0	1511	79787	797.87	1,595.74	2,393.61	3,191.48	3,989.35	4,787.22	5,585.09	6,382.96	7,180.83	435.3	9.7	76

12½	8	58	412.5	1528	80667	806.67	1,613.34	2,420.01	3,226.68	4,033.35	4,840.02	5,646.69	6,453.36	7,260.03	440.1	9.7	76
12½	10	60	437.5	1620	85556	855.56	1,711.12	2,566.68	3,422.24	4,277.80	5,133.36	5,988.92	6,844.48	7,700.04	468.8	10.0	79
13	8	60	442.0	1637	86436	864.36	1,728.72	2,593.08	3,457.44	4,321.80	5,186.16	6,050.52	6,914.88	7,779.24	471.6	10.0	79
13	10	62	468.0	1733	91520	915.20	1,830.40	2,745.60	3,660.80	4,576.00	5,491.20	6,406.40	7,321.60	8,236.80	499.4	10.3	82
13½	8	62	472.5	1750	92400	924.00	1,848.00	2,772.00	3,696.00	4,620.00	5,544.00	6,468.00	7,392.00	8,316.00	504.2	10.3	82
13½	10	64	499.5	1850	97680	976.80	1,953.60	2,930.40	3,907.20	4,884.00	5,860.80	6,837.60	7,814.40	8,791.20	533.0	10.6	85
14	8	64	504.0	1867	98560	985.60	1,971.20	2,956.80	3,942.40	4,928.00	5,913.60	6,899.20	7,884.80	8,870.40	537.8	10.6	85
14	10	66	532.0	1970	104036	1,040.36	2,080.72	3,121.08	4,161.44	5,201.80	6,242.16	7,282.52	8,322.88	9,363.24	567.6	10.9	88
14½	8	66	536.5	1987	104916	1,049.16	2,098.32	3,147.48	4,196.64	5,245.80	6,294.96	7,344.12	8,393.28	9,442.44	572.4	10.9	88
14½	10	68	565.5	2094	110587	1,105.87	2,211.74	3,317.61	4,423.48	5,529.35	6,635.22	7,741.09	8,846.96	9,952.83	603.4	11.3	92
15	8	68	570.0	2111	111467	1,114.67	2,229.34	3,344.01	4,458.68	5,573.35	6,688.02	7,802.69	8,917.36	10,032.03	608.2	11.3	92
15	10	70	600.0	2222	117334	1,173.34	2,346.68	3,520.02	4,693.36	5,866.70	7,040.04	8,213.38	9,386.72	10,560.06	640.2	11.6	95
15½	8	70	604.5	2239	118214	1,182.14	2,364.28	3,546.42	4,728.56	5,910.70	7,092.84	8,274.98	9,457.12	10,639.26	645.0	11.6	95
15½	10	72	635.5	2354	124276	1,242.76	2,485.52	3,728.28	4,971.04	6,213.80	7,456.56	8,699.32	9,942.08	11,184.84	678.1	11.9	98
16	8	72	640.0	2370	125156	1,251.56	2,503.12	3,754.68	5,006.24	6,257.80	7,509.36	8,760.92	10,012.48	11,264.04	682.9	12.0	99
16	10	74	672.0	2489	131414	1,314.14	2,628.28	3,942.42	5,256.56	6,570.70	7,884.84	9,198.98	10,513.12	11,827.26	717.0	12.2	101
16½	10	76	709.5	2628	138747	1,387.47	2,774.94	4,162.41	5,549.88	6,937.35	8,324.82	9,712.29	11,099.76	12,487.23	757.0	12.6	105
17	10	78	748.0	2770	146276	1,462.76	2,925.52	4,388.28	5,851.04	7,313.80	8,776.56	10,239.32	11,702.08	13,164.84	798.1	12.9	108
17½	10	80	787.5	2917	154000	1,540.00	3,080.00	4,620.00	6,160.00	7,700.00	9,240.00	10,780.00	12,320.00	13,860.00	840.3	13.2	111
18	10	82	828.0	3067	161920	1,619.20	3,238.40	4,857.60	6,476.80	8,096.00	9,715.20	11,334.40	12,953.60	14,572.80	883.5	13.5	114
18½	10	84	869.5	3220	170036	1,700.36	3,400.72	5,101.08	6,801.44	8,501.80	10,202.16	11,902.52	13,602.88	15,303.24	927.8	13.9	118
19	10	86	912.0	3378	178347	1,783.47	3,566.94	5,350.41	7,133.88	8,917.35	10,700.82	12,484.29	14,267.76	16,051.23	973.1	14.2	121
19½	10	88	955.5	3539	186854	1,868.54	3,737.08	5,605.62	7,474.16	9,342.70	11,211.24	13,079.78	14,948.32	16,816.86	1019.5	14.5	124
20	10	90	1000.0	3704	195556	1,955.56	3,911.12	5,866.68	7,822.24	9,777.80	11,733.36	13,688.92	15,644.48	17,600.04	1067.0	14.8	127
20½	10	92	1045.5	3872	204454	2,044.54	4,089.08	6,133.62	8,178.16	10,222.70	12,267.24	14,311.78	16,356.32	18,400.86	1115.5	15.1	130
21	10	94	1092.0	4044	213547	2,135.47	4,270.94	6,406.41	8,541.88	10,677.35	12,812.82	14,948.29	17,083.76	19,219.23	1165.2	15.4	133
21½	10	96	1139.5	4220	222836	2,228.36	4,456.72	6,685.08	8,913.44	11,141.80	13,370.16	15,598.52	17,826.88	20,055.24	1215.8	15.8	137
22	10	98	1188.0	4400	232321	2,323.21	4,646.42	6,969.63	9,292.84	11,616.05	13,939.26	16,262.47	18,585.68	20,908.89	1267.6	16.1	140
22½	10	100	1237.5	4583	242001	2,420.01	4,840.02	7,260.03	9,680.04	12,100.05	14,520.06	16,940.07	19,360.08	21,780.09	1320.4	16.4	143
23	10	102	1288.0	4770	251876	2,518.76	5,037.52	7,556.28	10,075.04	12,593.80	15,112.56	17,631.32	20,150.08	22,668.84	1374.3	16.7	146
23½	10	104	1339.5	4961	261947	2,619.47	5,238.94	7,858.41	10,477.88	13,097.35	15,716.82	18,336.29	20,955.76	23,575.23	1429.2	17.1	150
24	10	106	1392.0	5156	272214	2,722.14	5,444.28	8,166.42	10,888.56	13,610.70	16,332.84	19,054.98	21,777.12	24,499.26	1485.3	17.4	153
24½	10	108	1445.5	5354	282676	2,826.76	5,653.52	8,480.28	11,307.04	14,133.80	16,960.56	19,787.32	22,614.08	25,440.84	1542.3	17.7	156
25	10	110	1500.0	5556	293334	2,933.34	5,866.68	8,800.02	11,733.36	14,666.70	17,600.04	20,533.38	23,466.72	26,400.06	1600.5	18.1	160

Explanation of Table 1.—This table applies only to levees having side slopes of 2 to 1. The figures representing the equivalent borrow pit provide for a 20-foot "traverse" located at intervals of 300 feet. The figures representing cost are manipulated by moving the decimal point.

Example.—Required the cost per mile of a levee 6 feet high, with 6 feet crown, at 13½ cents per cubic yard.

From the table:
- Cost at 1 cent per cubic yard = $211.2; cost at 10 cents = $2112 .... $ 2112.00
- Cost at 3 cents per cubic yard = 633.6 .... 633.60
- Cost at 5 cents per cubic yard = 1056.0; cost at ½ cent = 105.6 .... 105.60

Adding, gives total cost per mile at 13½ cents per yard .... $ 2851.20

TABLE 2—Giving the number of cubic yards of material per linear mile in ditches of varying depths and widths.

Vertical Depth of Ditch	Average Width of Ditch								
	1 Foot	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet	7 Feet	8 Feet	9 Feet
Feet	*Cubic yards*	*Cubic yards*	*Cubic yards*	*Cubic yards*	*Cubic yards*	*Cubic yards*	*Cubic yards*	*Cubic yards*	*Cubic yards*
0½	97.78	195.56	293.34	391.12	488.90	586.68	684.46	782.24	880.02
1	195.56	391.12	586.68	782.24	977.80	1173.36	1368.92	1564.48	1760.04
1½	293.33	586.66	879.99	1173.32	1466.65	1759.98	2053.31	2346.64	2639.97
2	391.11	782.22	1173.33	1564.44	1955.55	2346.66	2737.77	3128.88	3519.99
2½	488.89	977.78	1466.67	1955.56	2444.45	2933.34	3422.23	3911.12	4400.01
3	586.67	1173.34	1760.01	2346.68	2933.35	3520.02	4106.69	4693.36	5280.03
3½	684.44	1368.88	2053.32	2737.76	3422.20	4106.64	4791.08	5475.52	6159.96
4	782.22	1564.44	2346.66	3128.88	3911.10	4693.32	5475.54	6257.76	7039.98
4½	880.00	1760.00	2640.00	3520.00	4400.00	5280.00	6160.00	7040.00	7920.00
5	977.78	1955.56	2933.34	3911.12	4888.90	5866.68	6844.46	7822.24	8800.02
5½	1075.55	2151.10	3226.65	4302.20	5377.75	6453.30	7528.85	8604.40	9679.95
6	1173.33	2346.66	3519.99	4693.32	5866.65	7039.98	8213.31	9386.64	10559.97
6½	1271.11	2542.22	3813.33	5084.44	6355.55	7626.66	8897.77	10168.88	11439.99
7	1368.89	2737.78	4106.67	5475.56	6844.45	8213.34	9582.23	10951.12	12320.01
7½	1466.67	2933.34	4400.01	5866.68	7333.35	8800.02	10266.69	11733.36	13200.03
8	1564.44	3128.88	4693.32	6257.76	7822.20	9386.64	10951.08	12515.52	14079.96
8½	1662.22	3324.44	4986.66	6648.88	8311.10	9973.32	11635.54	13297.76	14959.98
9	1760.00	3520.00	5280.00	7040.00	8800.00	10560.00	12320.00	14080.00	15840.00
9½	1857.78	3715.56	5573.34	7431.12	9288.90	11146.68	13004.46	14862.24	16720.02
10	1955.56	3911.12	5866.68	7822.24	9777.80	11733.36	13688.92	15644.48	17600.04
10½	2053.33	4106.66	6159.99	8213.32	10266.65	12319.98	14373.31	16426.64	18479.97
11	2151.11	4302.22	6453.33	8604.44	10755.55	12906.66	15057.77	17208.88	19359.99
11½	2248.89	4497.78	6746.67	8995.56	11244.45	13493.34	15742.23	17991.12	20240.01
12	2346.67	4693.34	7040.01	9386.68	11733.35	14080.02	16426.69	18773.36	21120.03
12½	2444.44	4888.88	7333.32	9777.76	12222.20	14666.64	17111.08	19555.52	21999.96
13	2542.22	5084.44	7626.66	10168.88	12711.10	15253.32	17795.54	20337.76	22879.98
13½	2640.00	5280.00	7920.00	10560.00	13200.00	15840.00	18480.00	21120.00	23760.00
14	2737.78	5475.56	8213.34	10951.12	13688.90	16426.68	19164.46	21902.24	24640.02
14½	2835.56	5671.12	8506.68	11342.24	14177.80	17013.36	19848.92	22684.48	25520.04
15	2933.33	5866.66	8799.99	11733.32	14666.65	17599.98	20533.31	23466.64	26399.97
15½	3031.11	6062.22	9093.33	12124.44	15155.55	18186.66	21217.77	24248.88	27279.99
16	3128.89	6257.78	9386.67	12515.56	15644.45	18773.34	21902.23	25031.12	28160.01

16½	3226.67	6453.34	9680.01	12906.68	16133.35	19360.02	22586.69	25813.36	29040.03
17	3324.44	6648.88	9973.32	13297.76	16622.20	19946.64	23271.08	26595.52	29919.96
17½	3422.22	6844.44	10266.66	13688.88	17111.10	20533.32	23955.54	27377.76	30799.98
18	3520.00	7040.00	10560.00	14080.00	17600.00	21120.00	24640.00	28160.00	31680.00
18½	3617.78	7235.56	10853.34	14471.12	18088.90	21706.68	25324.46	28942.24	32560.02
19	3715.56	7431.12	11146.68	14862.24	18577.80	22293.36	26008.92	29724.48	33440.04
19½	3813.33	7626.66.	11439.99	15253.32	19066.65	22879.98	26693.31	30506.64	34319.97
20	3911.11	7822.22	11733.33	15644.44	19555.55	23466 66	27377.77	31288.88	35199.99
20½	4008.89	8017.78	12026.67	16035.56	20044.45	24053.34	28062.23	32071.12	36080.01
21	4106.67	8213.34	12320.01	16426.68	20533.35	24640.02	28746.69	32853.36	36960.03
21½	4204.44	8408.88	12613.32	16817.76	21022.20	25226.64	29431.08	33635.52	37839.96
22	4302.22	8604.44	12906.66	17208.88	21511.10	25813.32	30115.54	34417.76	38719.98
22½	4400.00	8800.00	13200.00	17600.00	22000.00	26400.00	30800.00	35200.00	39600.00
23	4497.78	8995.56	13493.34	17991.12	22488.90	26986.68	31484.46	35982.24	40480.02
23½	4595.55	9191.10	13786.65	18382.20	22977.75	27573.30	32168.85	36764.40	41359.95
24	4693.33	9386.66	14079.99	18773.32	23466.65	28159.98	32853.31	37546.64	42239.97
24½	4791.11	9582.22	14373.33	19164.44	23955.55	28746.66	33537.77	38328.88	43119.99
25	4888.89	9777.78	14666.67	19555.56	24444.45	29333.34	34222.23	39111.12	44000.01

Explanation of Table 2.—The figures in the body of the table represent cubic yards. The partial duplication facilitates the use of the table. The figures are manipulated by the movement of the decimal point. Obviously, the average widths and vertical depths are interchangeable: and the table applies equally to ditches and levees, with any side slopes.

Example: Required the number of cubic yards of material per mile in a ditch 3½ feet deep, and 17 feet wide.

		Cubic yards
From the Table	Cubic yards in ditch 3½ feet deep, 1 foot wide = 684.44; for 10 feet wide = 6844.4	6844.4
	Cubic yards in ditch 3½ feet deep, 7 feet wide = 4791.08	4791.1
	Adding, gives total cubic yards per mile for ditch required	11635 5

TABLE 3.—Giving the number of acres in any right of way measured in feet, varas and miles.

Width of Right of Way	Area of Right of Way		
	Per 100 feet	Per 100 varas	Per mile
Feet	*Acres*	*Acres*	*Acres*
10	0.023	0.064	1.212
20	0.046	0.128	2.424
30	0.069	0.191	3.636
40	0.092	0.255	4.848
50	0.115	0.319	6.061
60	0.138	0.383	7.273
70	0.161	0.446	8.485
80	0.184	0.510	9.697
90	0.207	0.574	10.909

Explanation of Table 3.—The figures in the body of the table represent acres. These figures are manipulated by moving the decimal point.

Example.—Required the number of acres per mile in a right of way 62½ feet wide.

		Acres
From the table:	Acres in 60-foot width	7.273
	Acres in 20-foot width=2.424; for 2-foot width=0.242	0.242
	Acres in 50-foot width=6.061; for ½-foot width=0.060	0.060
	Adding, gives total number of acres per mile for width required	7.575